National Climate Change Process

Forest Sector Table

OPTIONS REPORT:

Options for the Forest Sector to Contribute to Canada's National Implementation Strategy for the Kyoto Protocol

November 1999

Preface

This Report was prepared by the Forest Sector Table with the assistance of the Canadian Forest Service of Natural Resources Canada and Environment Canada.

The views expressed in this paper are not necessarily those of the Government of Canada or those of the other organizations represented on the Table. We have tried wherever possible to create consensus about the views and recommendations presented in this Report. Where differences of opinion have been expressed they are reflected in the discussion.

The Table gratefully acknowledges the efforts of the many individuals and organizations who have contributed to the development of this document. The Report was drafted by Darcie Booth, Tony Lemprière and Tom Rosser of the Canadian Forest Service, with assistance from Terry Hatton and Michael Stephens of the Canadian Forest Service and Pascale Collas of Environment Canada. Tony Lemprière served as the coordinator of the report preparation.

Table Mandate

The Mandate of the Table is to analyse and evaluate forest sector options for contributing to Canada's national climate change response and their impacts on the broadly defined forest sector. The Table is to provide an integrating mechanism for all aspects of the climate change challenge for the forest sector and to explore issues not covered by other tables but of importance to the forest sector (e.g., forest-based communities, traditional uses, sector employment, forestry industry specific analysis).

Également disponible en français sous le titre:

Processus national de changement climatique Table du secteur forestier rapport sur les options: Options qui s'offrent au secteur forestier de contribuer à la Stratégie canadienne de mise en oeuvre du Protocole de Kyoto.

This publication is available on the Internet at:

http://www.nccp.ca

A limited number of copies of this report are available from:

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EXECUTIVE SUMMARY

1 Introduction

In December 1997, the Parties to the 1992 United Nations Framework Convention on Climate Change (FCCC) adopted a Protocol to the Convention (the Kyoto Protocol) to limit emissions of six greenhouse gases (ghg). Once the Protocol enters into force, the Annex 1 (industrialized) countries will have to reduce their average annual ghg emissions in 2008-12 by 5 percent below the 1990 level. Canada accepted a target of 6 percent below its 1990 level of 599 megatonnes CO_2-equivalent (Mt CO_2e).

In April 1998, the federal and provincial/territorial Ministers of Energy and Environment agreed to a process for developing a national implementation strategy on climate change, that would help determine the costs and impacts of reaching Canada's Kyoto Protocol target. This report presents the results of the work carried out over the last year under the auspices of the Forest Sector Table, one of sixteen Tables that were established as part of this process. The Table is made up of sector experts from a diverse array of stakeholder groups including the forest industry, environmental groups, organized labour, research organizations, academe, Aboriginal groups and forest dependent communities as well as governments.

The Table evaluated potential for the forest sector to help reduce Canada's ghg emissions and to offset emissions through carbon sequestration. Options were analysed in terms of their costs and mitigation potential as well as a number of other considerations including their implications for competitiveness, environmental and health impacts and employment. The various options presented here will be reviewed under the National Implementation Strategy and considered in relation to potential options suggested by other Tables.

The Kyoto Protocol and Canada's Forest Sector

Given that forests and the products that emanate from them literally embody carbon, few segments of Canadian society are more intricately linked to the climate change issue and the implementation of the Kyoto Protocol than the forest sector. The recognition of forests as sources and sinks of carbon in the Kyoto Protocol creates the potential for the forest sector to contribute to attaining Canada's target through sequestration efforts. In addition, the climate change phenomenon itself could have significant long-term impacts on Canada's forests.

The forest industry is Canada's largest industrial energy consumer and an important purchaser of chemicals and transportation services, so as a result Kyoto implementation has the potential to impact on the supply and price of most of the industry's major inputs. The forest products industry is Canada's leading manufacturing sector and a major economic force in all regions of the country. It accounts for 11% of Canada's manufacturing Gross Domestic Product (GDP) and provides jobs, directly and indirectly, to over 800,000 workers.

As an export oriented industry that sells over 70% of its output abroad, actions taken in Canada and internationally to deal with climate change could have serious implications for the global competitiveness of the forest industry. With net exports of $32 billion in 1997, the forest industry is by far the largest contributor to Canada's trade balance. Canada is the world's largest forest products exporter with $39 billion in exports representing approximately 18% of the global total in 1997.

The forest sector's predominantly rural base and the fact that it is Canada's largest non-urban employer add an additional challenge to addressing Kyoto. There are 340 communities across Canada that depend on the forest industry for their economic well being. The forest industry is also a major source of employment and business opportunities for Canada's Aboriginal peoples.

While the forest industry has already made significant strides in reducing its energy related ghg emissions, the Forest Sector Table believes that considerably more may be possible. With a supportive policy environment, the Table believes that the forest industry can make a contribution toward attaining Canada's Kyoto target that is disproportionate to its share of economic activity or ghg emissions.

II Methodology

The Table evaluated potential ways for the forest sector to help reduce Canada's emissions below the business-as-usual (BAU) level, or offset the BAU emissions through carbon sequestration. The technical feasibility and cost of specific actions was assessed as well the emissions impact over time. A qualitative assessment of competitiveness, environmental and health impacts was also carried out.

Cost effectiveness was estimated according to the cost curves guidelines provided to Tables, and is the net present value (NPV) of the incremental costs of each action divided by the emission reductions over the 'life' of the investment, where the life is the serviceable life of a new machine. Costs were calculated using a 10% discount rate. A negative cost effectiveness number means that an action has a net saving.

Tables were asked to present recommendations on specific measures - combinations of actions and policies to achieve each specific action, where 'policy' refers to an effort by government to realize an action. Thus a 'measure' involves the application of a policy for the purposes of achieving one or more actions. The Forest Sector Table analyzed a series of actions, determined key barriers to their realization and proposed a series of changes in government policy or other means to address these barriers.

The Table also determined the 'estimated incentive for realization.' This is the value of the incentive that would have to be provided to make an action financially attractive from the perspective of industry. For energy actions, it is equal to the NPV of the action, derived using a 40% discount rate. In other words, investment would be financially attractive if the size of the incentive was such that the pre-tax rate of return of the project, including capital costs, cost savings over time and the incentive, was equal to 40%. It is important to note that this is not necessarily a direct government incentive, but could be the result of any number of policies. It could include tax incentives, government programs, green energy pricing, etc. An incentive of zero is shown if the action has net savings in every province/region (i.e., a negative NPV) using a 40% rate. The use of the pre-tax 40% rate reflects the fact that the industry typically seeks a payback on the types of investments in question in two to four years. This reflects the limited capital, high debt loads, and shareholder demands for improved returns that confront the forest industry at this time. It is important to remember that financial feasibility is not the only factor limiting the realization of measures. Thus, in addition to ensuring an action to reduce emissions is financially feasible, public policy may also need to address other factors such as energy market regulations, lack of information, etc.

For afforestation measures, the incentive figures are the NPV of the planting and opportunity costs of the afforestation, derived using a 10% discount rate. This full cost would not necessarily be borne by federal or provincial governments, as the Table believes that there are many possible groups, such as forestry companies, energy companies, municipalities, conservation authorities, and others, who may choose to wholly or partially fund afforestation. On the other hand, there are other costs and benefits which we did not calculate or include in the estimates. There are a number of program design considerations that are discussed in the paper and that would need to be more fully scoped out prior to implementing any afforestation programs.

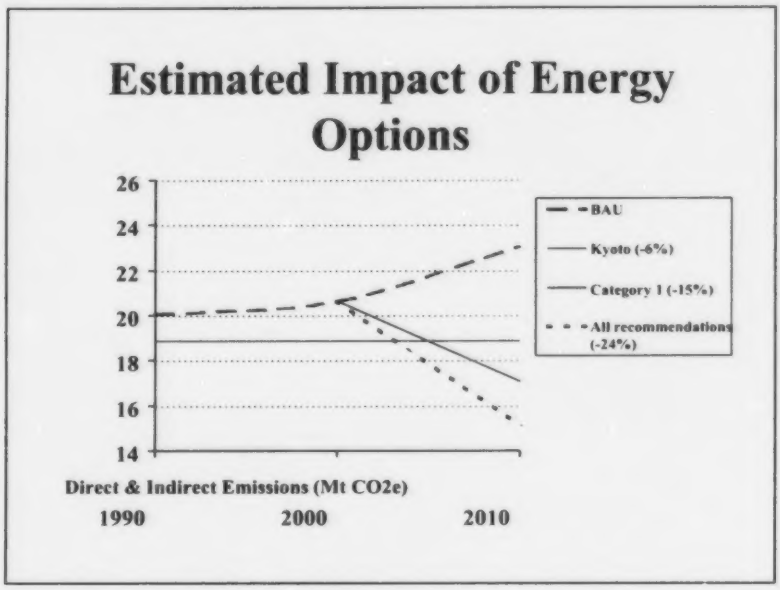
III Forest Sector Table Energy Options

The forest industry is unique among major industrial energy consumers in that its production processes and by-products create the potential for the industry to self-generate renewable energy and virtually eliminate fossil fuel CO_2 emissions. Between 1990 and 1997, the industry's direct emissions declined by close to 10 percent despite significant increases in industry production. These reductions resulted from both declines in the industry's energy intensity as well as increases in the proportion of its energy needs derived from biomass. The use of biomass for energy is considered to have no net emissions of CO_2. Substitution of biomass energy for fossil fuels has been under way for over 20 years and biofuels now account for over 50% of the industry's energy consumption. Although the forest industry's production is projected to increase by more than 40 percent over the 1990-2010 period under a business-as-usual (BAU) scenario, direct ghg emissions are projected to decline by 3 percent and total emissions will grow by 15 percent.

Summary of Actions Evaluated

The Forest Sector Table Options paper presents an analysis and prioritization of 17 separate energy actions, of which 15 are recommended for immediate implementation or further consideration as part of Canada's Kyoto implementation strategy. The Table believes its Options Report can serve as the basis for developing a strategy that could result in a very significant reduction in the forest industry's direct and indirect emissions. The Table estimates that realization of those actions that can be implemented immediately (Category 1 actions) would result in emission reductions of nearly 6 MT or about 26 percent below BAU levels in 2010 and 15 percent below 1990 levels. Implementation of all of the Table's energy recommendations is estimated to reduce emissions by a further 2 MT and result in reductions of about 35 percent below BAU by 2010 and 25 percent below 1990 levels (See Figure E.1).

Figure E.1 - Estimated Impact of Energy Options Relative to BAU



The energy actions evaluated by the Table cover 3 main areas:

Energy Efficiency -These actions result in reductions in energy use through the adoption over time of more energy efficient technologies or through better use of existing equipment, whether through improved maintenance or through taking a systems approach to energy flows in mills. The high hurdle rates applied by the industry to these types of investment tend to be a major barrier to the realization of these actions.

Fuel-Switching- These actions result in reductions in ghg emissions through greater use of renewable biomass energy. Burning wood biomass is considered to result in no net CO_2 emissions as the emissions will be balanced by carbon sequestration if the wood biomass is derived from sustainably managed forests. An economic supply of wood residues or alternate biomass feedstock, financial feasibility and the ability to sell excess electricity into the grid are key to realizing these actions.

Emerging Technologies- The Table believes that the commercialization of a number of technologies currently under development could allow the forest industry to realize significant reductions in its ghg emissions. These actions are based on the application of technologies or approaches which are not now commercially available or applied in Canada, but which the Forest Sector Table believes have a good chance of being applied by 2010. Efforts to accelerate research, development, commercialization and dissemination of specific technologies are key to realizing these actions.

Key Impediments to Energy Actions

The Forest Sector Table identified seven key impediments that can discourage or prevent forest industry investment in energy-saving and ghg emission reduction actions. These barriers will need to be addressed in order to be able to achieve the large ghg emissions reductions that are indicated by the analysis of potential actions.

1 **High hurdle rates.** The forest industry faces a number of factors which collectively result in high hurdle rates being applied to potential capital expenditures. Among these factors are limited resources, pronounced cyclicality in profits, a history of low returns coupled with a fundamental shift in shareholders toward greater ownership by large institutional investors who demand higher returns, and requirements to comply with current effluent and air pollution regulations.

2 **Achieving more efficient energy use is not a high priority.** Energy costs are not a large part of costs except in certain segments of the forest products industry such as newsprint and some panelboards (and note that reducing energy use is not always the same as reducing ghg emissions in terms of complying with the Protocol - for example, reducing the use of biomass energy does not reduce CO_2 emissions). Coupled with high hurdle rates, this generally means that projects devoted only to changing energy use are seldom implemented.

3 **Lack of knowledge/information.** Mill managers may lack information on energy efficiency cost-saving opportunities. As well, there may be a lack of personnel at the mill level with a clear mandate to control energy use and an understanding of how to do so.

4 **Risk averse approach to new technology.** The financial situation of the industry, in conjunction with the fact that some technology decisions must be lived with for 20-40 years, means that the approach to new and emerging technologies is risk adverse. Early implementors of a new technology face particular problems.

5 **Promising technologies are not yet commercial, or are not applied in the Canadian industry.** Some potentially very useful technologies for ghg emission reduction are not yet at the commercial stage and need further work to resolve difficulties, or have not been adopted in the forest industry in Canada. In part this reflects that difficulty the industry faces in raising capital for implementing proven technologies, let alone exploring emerging technologies.

6 **Structure of electricity markets.** Among other things, regulations, utility behaviour and economics limit or prevent the sale of excess electricity by pulp and paper mills, which acts as a disincentive to any investments which produce excess electricity. Province-wide average electricity and transmission prices provide a disincentive to renewable energy and cogeneration initiatives by independent power producers.

7 **Lack of secure wood waste supply.** This impediment includes issues of a stable, sufficient supply at attractive delivered prices. Transportation costs are the major component of residue costs and a key barrier to greater use of existing residue surpluses in parts of Canada.

Core Policy Requirements - Energy Measures

In order to overcome the impediments listed above, the Table has identified a number of changes to government policies or other means to encourage ghg reductions within the sector. However, the Table believes that the three policy areas identified below are of critical importance in allowing the forest industry to realize its considerable potential to contribute to Canada's Kyoto response and deserve particular attention.

Provide fiscal incentives to reduce capital constraints: The Forest Sector Table believes that the industry's financial position and resulting difficulties in raising capital represent a major, likely the major, impediment to the realization of investments that could substantially reduce its ghg emissions. The Table believes that fiscal incentives provide a rapid, efficient and cost-effective means of creating the needed inducement to attract investment in these actions. In Table E.2, an estimate of the magnitude of the incentive required to realize each action is provided. In theory, incentives could be delivered through a funded government program rather than a tax expenditure; however, the Table believes the latter approach is likely to entail lower administrative costs and is the most efficient and neutral means of reducing emissions.

Provide policies to encourage renewable energy: The Forest Sector Table believes that the increased use of forest biomass as an energy source in many settings holds tremendous potential to contribute to Canada's Kyoto response and that a more supportive policy environment could allow many segments of the Canadian forest industry to become net sources of renewable energy. Central to realizing this opportunity is the establishment of electricity markets where mills can sell any excess power they generate either into the grid or directly to users at fair prices. For example, the establishment of renewable energy set-asides, similar to those in place in many US states and as proposed federally in the US, could play a key role in increasing the use of biomass cogeneration within the Canadian forest industry.

Encourage technology and innovation: As one of Canada's leading consumers of high technology machinery and equipment, the development and commercialization of new technologies holds considerable potential to contribute to reducing the forest industry's ghg emissions. The Table believes that a concerted research and development effort involving all stakeholders in Canada's forest industry research community is a priority element for engaging this sector in a Kyoto strategy and a key focus of such an effort should be encouraging the commercial application of promising new technologies. Innovative programs which serve to reduce or share the risks associated with this critical step in the innovation process could help to accelerate technology development and penetration rates.

The opportunities for reducing direct and indirect ghg emissions in the forest products industry tend to be very localized in nature, and hence the best way to achieve reductions is to put in place policies and incentives that allow firms to determine which investments make sense for their particular circumstances, as opposed to regulating across the broad standards or requirements. In addition, each mill uses a different mix of fuels with varying carbon intensities to meet its energy needs so that the relationship between energy efficiency and ghg intensity varies widely. For these reasons, the feasibility and cost-effectiveness of actions to reduce ghg emissions in this industry vary widely across regions, industry-sectors and from one mill to the next. As a result, conventional regulatory approaches seem unlikely in most cases to provide a cost-effective means of reducing ghg emissions in the forest industry.

IV The Forest Sector Table and Carbon Sequestration Options

A sink is an activity or process that removes CO_2 from the atmosphere and a source is an activity or process that emits CO_2 to the atmosphere. The Table considered options related to increasing forestry sinks and reducing forestry sources for those sources and sinks that are or may be included under the Kyoto Protocol. Currently under the Kyoto Protocol, Canada will get credit for removals in 2008-12 associated with reforestation, afforestation and deforestation (RAD) since 1990, and will receive a debit for emissions in 2008-12 associated with these activities.

Canada's potential net offset from RAD will become clear only after a number of outstanding issues are resolved through international negotiation. A key uncertainty is how the three activities will be defined - different definitions can result in vastly different sizes of sinks or sources. As well, agreement is needed on what measurement systems will be acceptable and what carbon pools will be included (i.e., just above-ground biomass or all carbon pools including soils). Finally, the Protocol allows for discussions on what additional direct human-induced activities in the agricultural soil and land-use, land-use change and forestry categories should be added to the RAD activities. The potential contribution of forest sinks to meeting Canada's Kyoto Protocol target will depend in large part on the outcome of these negotiations. This complicates the assessment of options for inclusion in the Kyoto Protocol.

Afforestation

Afforestation is probably subject to the least uncertainty in terms of definitions thought there are potentially important accounting and measurement uncertainties. Afforestation has relatively high certainty of being defined in a way such that the options assessed by the Table are relevant and these are the only carbon sequestration options for which the Table prepared detailed action analyses. Actions analysed include regional afforestation programs using traditional slower-growing trees species, plantations using fast-growing tree species, and increased planting of shelterbelts.

Reforestation

The definition of reforestation for the purposes of the Protocol is highly uncertain and negotiations to agree on a definition likely will not be completed until at least late 2000 . The Table's report includes a discussion of potential actions to increase the carbon sequestered due to reforestation but does not provide estimates of ghg sequestered or cost effectiveness due to data and time limitations. While the changes in carbon stocks between 2008 and 2012 on areas reforested since 1990 may be used to offset Canada's target in the commitment period, the potential impact is heavily dependent on the definition of reforestation under the Kyoto Protocol. There are two distinctly different interpretations that are critical to any forecasts of estimates of future potential. At issue is whether the re-establishment of trees after harvesting, i.e., regeneration, is included under the Protocol as reforestation or not.

The Table discussed potential actions assuming that the negotiations resulted in a definition of reforestation similar to the one used by the United Nations Food and Agriculture Organization (FAO) and proposed by Canada. Under this definition, reforestation would include the re-establishment of trees after harvesting. Thus the actions discussed are those which will potentially increase carbon sequestration on areas regenerating after harvest since 1990, as well as on areas to be harvested in the future, relative to the BAU case. While some Table members endorse the proposed Canadian definition of reforestation, other Table members questioned its appropriateness and felt that it was unlikely this definition would be accepted.

Deforestation

The eventual definition of deforestation for the purposes of the Protocol is also uncertain. Under the Protocol, deforestation in the 2008-2012 time period will be counted as a source of CO_2 emissions, and will thus increase the mitigation effort required to meet Canada's emission reduction target for the commitment period. Deforestation is not included in the 1990 baseline level so that the full level of deforestation in the commitment period is a liability, in the sense that emissions from deforestation will increase Canada's BAU emissions in the future, making it harder to achieve the target.

Despite the uncertainties surrounding its measurement and definition, deforestation could give rise to a significant carbon debit for Canada in the first commitment period; as a result, policies and actions to reduce current rates of deforestation should be carefully considered in the development of Canada's overall climate change strategy. However, any policy initiatives in this area will need to be balanced against other economic and policy objectives, such as regional economic development and employment generation in those regions where deforestation is occurring. While the Table did conduct research in this area, the lack of definitive information on the extent, location and ghg emission impact of current deforestation activities left it unable to develop specific policy proposals for the Options paper.

Forest Management and Other Activities

The Protocol makes provision for negotiations to add additional human-induced activities resulting in emissions from sources and uptake by sinks in forests to the current list of reforestation, afforestation and deforestation. As a result, various activities have been proposed that could enhance carbon sinks in forests. These include specific forest management activities such as thinning, fertilization and fire protection. Canada and a few other countries have proposed a "managed forest" approach as an alternative to the current RAD provisions of the Protocol, in order to address some of the current imbalances in the Protocol. This approach would provide a full accounting of changes in carbon stock within the specified managed forest area, and would ensure that all forest management activities that result in carbon stock increases or decreases are accounted for.

There are a number of potential actions that could increase the net carbon stock of the managed forest, and therefore increase the net potential contribution of the managed forest to achieving Canada's emission reduction target. Forest management strategies which have been proposed for increasing carbon sequestration include:

- reducing the regeneration delay after natural disturbances or harvest through planting or seeding;
- restoration of degraded sites and NSR (not sufficiently restocked) lands; use of genetically enhanced trees;
- fertilization;
- control of pests and diseases;
  increased protection from fire;
- commercial thinning;
- juvenile spacing;
- increasing rotation age;
- changing species mix (e.g., planting fast-growing short-rotation hybrid species);
- reducing harvest levels (i.e., set-asides); and
- changing harvest methods.

At this point, the impact of these management strategies on net carbon sequestration is still uncertain - the Table's report discusses them but does not provide estimates of ghg sequestered or cost effectiveness due to data and time limitations. Further work is needed to assess their impact on all carbon pools, as well as the nature of carbon benefits in the long-term. The Table also considered the issue of carbon stored in forest products.

V Forest Sector Measures Recommendations

The approach to the national strategy for achieving the Kyoto target is based on developing a core options package for immediate implementation in 2000, as well as considering elements of a longer term package for implementation in the post-2000 period. Implementation means putting in place policies to facilitate the actions. In keeping with this approach, each measure analysed by the Table is shown in Table E.1 and is placed in one of four categories. The Table was not able to reach consensus on all of its recommendations for measures and Table E.1 indicates where consensus did not exist.

Category 1: This category of recommendations refers to measures that can be implemented immediately (ie. in 2000) and should be part of a package of core measures in Canada's national strategy to reduce its ghg emissions to meet the 2008-12 goal.

Combined, the eight consensus forest industry energy measures in this category (measures 1 to 8 in Table E.1) form an options package that could reduce the forest industry's direct and indirect emissions by a maximum of about 9.0 Mt CO_2e in 2010. The interactions among these actions are estimated to reduce the emission reductions by 25-50%. Reducing by 33% to account for the interactions suggests that a sizeable reduction of about 6.0 Mt CO_2e in 2010 is achievable. This is equivalent to a 15% drop below 1990 emissions. We estimate that the incentives required to make the energy actions in this category financially feasible would have a maximum value equivalent to 1997$1.2 billion (the actual value could be lower given the interactions among the actions). Other additional indirect government support or policy changes would also be required. For example, the wood waste cogeneration measure requires changes in electricity transmission pricing.

The non-consensus recommendation for afforestation using fast-growing species, if implemented, would offset ghg emissions by sequestering 1.3 Mt CO_2e in 2010. Planting and land opportunity costs total about 1997$140 million but note that a full accounting of all costs and benefits was not possible. Also note that there are considerable concerns about afforestation on the part of some Table members.

Category 2: **These recommendations concern prospective measures that should play a role in Canada's strategy for meeting its emission reduction target but which, for example, require further analytical work and/or broader consultation, or are conditional on international developments, including the outcome of negotiations to refine the Kyoto Protocol. Thus these measures should be the basis for developing a future package of measures to reduce or offset Canada's ghg emissions in 2008-12. While full implementation might not occur in 2000, it should not be delayed much beyond 2000, and policy development should start in 2000.**

Collectively, the six consensus forest industry energy measure recommendations included in this category (measures 10-15 in Table E.2) would have a maximum emission reduction impact of 4.9 Mt CO_2e in 2010. However, their combined impact is likely to be much lower due to interactions among the measures and the effect of wood residues shortages in many parts of the country. Thus these six measures are estimated to reduce emissions by roughly 2.0 Mt CO_2e in 2010, after accounting for these effects.

We estimate that the incentives required to make the energy measures in this category financially feasible from the industry perspective would have a maximum value equivalent to about 1997$0.9 billion (the actual value could be lower given the interaction among the actions). Additional government support would be required to address the other impediments including lack of capital, high risk, and the inability to sell excess electricity at economic prices.

The wood ethanol measure is estimated to reduce emissions by 0.36 Mt CO_2e by replacing gasoline with a blend of gasoline and biomass-based fuel. The incentive required for realization would have a value of $120 million, but development, demonstration and commercialization of the technology would require additional support.

The Table did not reach a consensus on the advisability of the measures involving afforestation of almost 800,000 ha over 15 years, beginning in 2001. If implemented, these afforestation measures collectively would provide an emission offset of 0.8 Mt CO_2 in 2010. A delay in the start-up date from 2001 to 2002 or 2003, which is likely more realistic, will reduce the emission offset in 2010 by roughly 35%. Over the longer term, annual emission offsets would be much higher - the average annual offset over the 2000 - 2050 period is 4.1 Mt CO_2e per year, or a total of over 200 Mt over the 50 years. The upfront planting and opportunity cost of planting 800,000 ha over 15 years is about 1997$0.6 billion, but there would be other costs and benefits as well which we were not able to estimate. Due in part to these uncertainties, some Table members were unwilling to endorse these measures.

Category 3: **Measures which merit further consideration but are longer term and require additional analysis/information for inclusion in the evolution of a post-2000.**

The Table did not classify any of the measures it evaluated in this category.

Category 4: **Measures that do not merit further consideration, as demonstrated by the results of the assessment.**

Two measures were assigned to this category.

Table E.1
Summary of Forest Sector Measures
(See text for explanation of the Table)

Measure and Category of Recommendation	Type of Measure	Cost Effectiveness 1997$ / t CO_2e Reduced or Offset (10% discount)	GHG Emission Reduction or Offset, 2010 Mt CO_2e	Estimated Incentive for Realization 1997$ million	Section in Report
CATEGORY 1 MEASURES					
1 Select high energy-efficiency auxiliary technology - pulp and paper mills	energy efficiency	-90.8	0.65	0	3.4.5
2 Improve maintenance/use of existing auxiliary equipment - pulp and paper mills	energy efficiency	-64.1	0.36	0	3.4.3
3 Improve maintenance and use of existing steam-producing equipment - pulp and paper mills	energy efficiency	-61.3	0.85	0	3.4.3
4 Improve process thermal integration - pulp and paper mills	energy efficiency	-31.8	1.25	0	3.4.1
5 Select energy efficient process technologies - pulp and paper mills	energy efficiency	-24.1	2.68	839	3.4.2
6 Optimize recovery boilers - 35 pulp and paper mills	fuel-switching	-15.2	0.39	65	3.5.3
7 Increase wood waste cogeneration - 12 pulp and paper mills (mills sell excess electricity)	fuel-switching	-11.1	2.46	247	3.5.4
8 Select high energy-efficiency technologies - lumber and panelboard mills	energy efficiency	4.4	0.33	57	3.4.6
9 Plant fast-growing plantations - 50,000 ha planted over 5 years **NOT CONSENSUS**	afforestation	22.2	1.31	141	4.2.3
CATEGORY 2 MEASURES					
10 Select high intensity driers - paper mills	emerging technology	-85.9	0.21	0	3.6.4
11 Black liquor integrated gasification and combined cycle cogeneration - 3 pulp and paper mills (mills sell excess electricity)	emerging technology	-21.1	1.09	0	3.6.2
12 Fuel-switching - lumber and panelboard mills	fuel-switching	-5.4	1.51	356	3.5.5
13 Increase number of hog fuel boilers - 12 pulp and paper mills	fuel-switching	-3.4	1.33	111	3.5.2
14 Modernize of hog fuel boilers - 35 pulp and paper mills	fuel-switching	-2.6	0.48	155	3.5.1
15 Reduce water use through progressive system closure - 10 pulp and paper mills	emerging technology	5.3	0.31	200	3.6.1
16 Develop 2 wood-ethanol plants	other energy	6.8	0.36	119	3.7.1

Measure and Category of Recommendation	Type of Measure	Cost Effectiveness 1997$ / t CO_2e Reduced or Offset (10% discount)		GHG Emission Reduction or Offset, 2010 Mt CO_2e		Estimated Incentive for Realization 1997$ million	Section in Report
		2008-2012	2000-2050	In 2010	Average 2000-2050		
17 Initiate afforestation program(s) using traditional species							
a Prairie block plantations - 260,000 ha planted over 15 years **(NOT CONSENSUS)**	afforestation	115	3	0.37	1.4	214	4.2.5
b Prairie shelterbelts - 169,000 ha planted over 15 years **(NOT CONSENSUS)**	afforestation	141	3.7	0.15	0.6	107	4.2.4
c Eastern block plantations - 195,000 ha planted over 15 years **(NOT CONSENSUS)**	afforestation	145	2.3	0.22	1.4	157	4.2.7
d BC block plantations - 169,000 ha planted over 15 years **(NOT CONSENSUS)**	afforestation	453	2.4	0.04	0.7	86	4.2.6
Total (793,000 ha over 15 yrs) **(NOT CONSENSUS)**		144	2.8	0.78	4.1	564	4.2
18 Policies to increase carbon sequestration on the managed forest **(not currently in Protocol)**	other carbon sequestration	further analysis needed					4.5
19 Modify reforestation methods to increase sequestration **(high negotiating uncertainty) (NOT CONSENSUS)**	reforestation	further analysis needed					4.3.2
20 Implement policies to reduce deforestation **(negotiating uncertainty)**	deforestation	further analysis needed					4.4
CATEGORY 3 MEASURES							
No measures in this category							
CATEGORY 4 MEASURES							
21 Lignin precipitation / improve recovery boiler operation - 45 pulp and paper mills	emerging technology	20.2		0.22		146	3.6.5
22 Biomass gasification to feed lime kilns - 10 pulp and paper mills	emerging technology	47.1		0.31		287	3.6.3

Note: a negative cost per tonne indicates that the emission reduction is achieved with a net savings.

VI Other Table Recommendations

While the focus of the Forest Sector Table has been on analysing options for the sector to contribute to ghg mitigation, the Table has also considered other aspects of a Kyoto Implementation Strategy that are of relevance to the sector. In the course of its work, the Table has developed a series of principles and directions that it believes should be observed in the development of a National Implementation Strategy for the Kyoto Protocol. They are:

1 That the continued involvement of representatives of all stakeholder groups in the development of a National Implementation Strategy is critical, given the far-reaching implications of Kyoto for all segments of Canadian society. Care must be taken to maintain appropriate balance between stakeholder groups.

2 That a National Implementation Strategy recognize the uncertainties associated with the Protocol itself and the response of Canada's trading partners to it by being flexible so that Canada's strategy can adapt to international developments as they evolve.

3 That implementation is most likely to achieve mitigation targets in a timely and cost-effective manner if it relies on broadly based market-oriented policy instruments and approaches, accompanied by effective regulatory frameworks and the removal of inappropriate incentives and disincentives.

4 That the timely removal of uncertainties around systems of credit for early action and baseline protection are key to their potential contribution to a National Implementation Strategy.

5 That the competitive, employment, health and environmental impacts of both a National Implementation Strategy as a whole, and the individual measures proposed as part of it, need to be more fully determined.

6 That use be made of full life-cycle and systems approaches in policy development wherever possible, including in the development of building codes and standards.

Recommendations for Further Actions and Measures Analysis

The Forest Sector Table has made every effort to fulfill its mandate in as comprehensive and objective a manner as possible. However, time limitations meant that the Table was unable to assess all potential actions that were identified by members and stakeholders. The following actions should be assessed to determine their potential for ghg emission reduction or carbon sequestration potential.

10) increased use of recycled fibres on pulp and paper industry emissions
11) improved energy efficiency in logging and silviculture operations
12) ways to reduce the ghg emission impacts of transportation services used by the forest industry
13) opportunities outside the forest industry for fuel-switching to wood biomass
14) ways to reduce the impact of deforestation (need to first better understand its causes, location and extent)
15) there is a very high priority to determine the implications for Canada of including the managed forest and storage of carbon in forest products in the Protocol
16) carbon sequestration and energy-saving impacts of urban forestry.

Recommendations for Further Background Work

During the course of its work, the Table identified a number of important background issues and information gaps that it was unable to address but believes should be the subject of further analysis. These include:

1) improve information on availability of biomass wastes for energy
2) improve information on tree growth and yield, and changes in all carbon pools over time
3) improve information on factors which determine the cost and impact of afforestation programs
4) potential ownership rules for carbon credits and debit on public lands under tenure arrangements with private companies
5) carbon sequestration impact and costs of forest management activities on forest carbon pools over time
6) information on the impact and cost of actions to modify carbon storage of carbon in forest product carbon pools, and their links to onsite carbon storage in all pools over time
7) development of systems to measure changes in carbon stock resulting from afforestation, deforestation and reforestation and other activities on the managed forest.

VII Conclusions

Both the climate change phenomenon itself and Canada's national response to it pose significant risks to the long-term well being of the forest sector. However, the Table believes that a supportive policy environment combined with concerted action on the part of sector stakeholders can allow the sector to make a disproportionate contribution toward the Kyoto target without imposing undue burden on any stakeholder group. Much can be done in the next 5-10 years, using proven technologies and methods. In time, even more may be possible as new and emerging technologies are developed and become widely available.

1.0 INTRODUCTION

In December 1997, the Parties to the 1992 United Nations Framework Convention on Climate Change (FCCC) adopted a Protocol to the Convention (the Kyoto Protocol) to limit emissions of six greenhouse gases (ghg). The Protocol will enter into force as a legally-binding agreement when 55 countries covering at least 55 percent of FCCC Annex I country emissions have ratified the Protocol. The Annex I countries are the developing countries and countries in the process of transition to a market economy (eg. Russia, Ukraine, Latvia, Romania, Bulgaria etc.) that accepted, among other things, a voluntary commitment in the FCCC to reduce their ghg emissions to 1990 levels by 2000. Once the Protocol enters into force, the Annex 1 countries will then have to reduce their average annual ghg emissions in 2008-12 by 5 percent below the 1990 level. Canada accepted a target of 6 percent below its 1990 level of 599 megatonnes CO_2-equivalent (Mt CO_2e).

Shortly after the adoption of the Protocol, Canadian First Ministers asked their energy and environment ministers to examine the consequences of the Kyoto commitments and to develop a process to ensure full participation of the provincial, territorial and federal governments in the examination. In April 1998, federal and provincial/territorial Ministers of Energy and Environment agreed to a process for developing a national implementation strategy on climate change. The process is to engage stakeholders and to examine the impact, costs and benefits of potential options to achieve Canada's target.

Sixteen Tables were established to focus on major parts of this work. Two Tables focussed explicitly on forest sector issues. The Forest Sector Table was created to provide an integrated view of the sector. A Sinks Table, with significant representation from the forest sector, was created to provide advice on carbon sequestration in forest, agricultural and other sinks. In this report the forest sector is defined to include the forest industry, the forest resource, and the variety of interests associated with them in some way. The forest industry includes both forest products manufacturing (pulp and paper as well as solid wood products) and commercial logging and forestry.

This report presents the results of the work carried out under the auspices of the Forest Sector Table between fall 1998 and summer 1999. The Table evaluated potential ways for the forest sector to help reduce Canada's emissions below the business-as-usual (BAU) level, or offset the BAU emissions through carbon sequestration. Options were analyzed in terms of the emissions impact over time, the expected cost per tonne of ghg mitigated, implications for competitiveness and employment, as well as other considerations. The various options presented here will be reviewed under the National Implementation Process and considered in relation to other potential options suggested by other Tables.

It should be noted that the focus of this work has been on options to help Canada achieve the Kyoto Protocol target, and not specifically to address the issue of climate change as a whole, or the objectives of the Framework Convention on Climate Change. In other words, options that were not likely to affect Canada's target were not considered, even though they might be effective in reducing greenhouse gas emissions or sequestering carbon. For example, the Kyoto Protocol limits those activities that can be considered for carbon sequestration credits to reforestation, afforestation and deforestation since 1990 (see Chapter 4). It was considered unlikely that planting in urban forests would be accepted under the Protocol. Because this activity was unlikely to gain Canada any carbon credits under the Protocol, this option was not studied, even though it may have real potential for removal of greenhouse gases from the atmosphere.

Chapter 1 of this report presents an overview of the Table's approach while Chapter 2 summarizes some of the broader forest sector perspectives that need to be taken into consideration in the development of a National Climate Change Strategy. Chapters 3 and 4 summarize the analysis of energy options and carbon sequestration options, respectively. Chapter 5 presents the recommendations on options. A list of analytical studies commissioned by the Forest Sector Table are found in Annex A.

1.1 MAJOR AREAS OF FOCUS AND ANALYTICAL APPROACH

1.1.1 Choice of Actions for Analysis - The Actions Matrix

This Report presents a wide range of actions and measures to promote ghg mitigation within the forest sector through energy efficiency improvements in the forest products industry, increased use of forest biomass for energy and increased forest carbon sequestration. Chapters 3 and 4 of this Report present 22 individual actions which the Table believes could contribute to increasing ghg mitigation within the forest sector. However, there are a significant number of other possible actions within the sector that could reduce emissions or promote sequestration which were not reviewed in sufficient detail to be presented as options in this paper. Given the time and resource limitations facing the Table, it simply was not possible to thoroughly evaluate every conceivable action to mitigate ghg emissions within the forest sector.

In its Foundation Paper, the Forest Sector Table identified and listed a range of ghg mitigation actions. Subsequent to the publication of the paper, this list was expanded through the addition of other actions identified by Table members and became the Forest Sector Table "Actions Matrix". In the fall of 1998, Table members reviewed the matrix and, based on their judgement and experience, evaluated the potential ghg impact, cost and timing of each action. Based on these considerations, and recognizing the time and resource limitations facing the Table, they also assigned a priority to each of the actions as a guide to further research. In developing its research program, the Table used the results of this exercise to set its research priorities.

The Actions Matrix is shown in Table 1.1.1. Those actions identified as being of higher priority were considered for further study in the Table's research program. In the course of its work, the Forest Sector Table commissioned 25 separate research projects between October, 1998 and June 1999 which together form the basis of much of the analysis contained in this Report. A complete bibliography of these studies is listed in Annex A. Most of these research projects focussed on evaluating the ghg mitigation potential, cost and cost effectiveness of individual actions as well as impediments to their realization. In many cases, the studies also examined changes to government policies or other means that could be employed to realize the potential of these actions. Many of the studies also explore the potential competitive, employment, environmental, health or other non-ghg related impacts that these actions or the policies needed to realize them might entail. In the course of its research program, the Table has tried where possible to identify regional impacts of the actions.

Table 1.1.1
Forest Sector Table Actions Matrix

Action	*A Priori* Assessment of Impact			Priority for Analysis	Status / Section in Report
	GHG Impact	Cost	Time Frame		
A ENERGY OPTIONS - FOREST PRODUCTS INDUSTRY					
1 IMPROVE ENERGY EFFICIENCY OF EXISTING EQUIPMENT					
1.1 systems approaches					
a paper and allied products industry	medium	low	short-medium	high	3.4.1
b wood products industry	low	low	short-medium	medium	not presented
1.2 on-line energy monitoring and management	low	low	short-medium	medium	3.4.1
1.3 improve in-house maintenance and repair	low	low	short-medium	medium	3.4.3 and 3.4.4
2 ADOPT MORE ENERGY-EFFICIENT PROCESSES AND EQUIPMENT					
2.1 install more efficient equipment in paper and allied products industry	medium-high	medium-high	medium	medium-high	3.4.2, 3.4.5
2.2 increased use of cogeneration					
a paper and allied products industry	high	medium-high	short-long	high	3.5.4
b wood products industry	low-medium	medium-high	short-long	medium	3.5.5

Action	*A Priori* Assessment of Impact			Priority for Analysis	Status / Section in Report
	GHG Impact	Cost	Time Frame		
2.3 development/adoption of new/emerging technologies in the pulp and paper industry					
a advanced turbine systems	high	high	short-medium	medium-high	not presented
b black liquor gasification	medium	high	medium-long	medium-high	3.6.2
c biomass gasification	high	high	long	medium-high	3.6.3
d integrated gasification combined cycle	medium	high	long	medium-high	3.6.2
e more efficient paper drying equipment	medium	high	short-medium	medium	3.6.4
2.4 Adopt more energy efficient equipment in wood products industry	low-medium	medium	short-medium	medium-high	3.4.6
2.5 change logging industry energy use					
a change logging practices	low	medium	medium	low	not presented
2.6 change transportation energy use	low	?	?	low-medium	not presented
2.7 increase use of recycling	low-medium	medium	medium	low	not presented
2.8 increase use of biotechnology in pulp and paper					
a biotech to change fibre characteristics	low-medium	medium	long	low-medium	not presented
b biotech in pulping and bleaching processes	low-medium	medium	long	low-medium	not presented
2.9 Manufacture of paper from non-wood resources	low	high	long	medium	not presented
3 ENCOURAGE FUEL SWITCHING					
3.1 Increase use of natural gas					
a paper and allied products industry	low-medium	medium	medium	low-medium	not presented
b wood products industry	low	medium	medium	low-medium	3.5.5
3.2 Increase use of biomass in pulp and paper					
a improve hog fuel quality	low-medium	low-medium	short	medium-high	not presented
b retrofit/upgrade fossil fuel boilers to allow co-firing	medium	medium	medium	medium	3.5.2
c retrofit/upgrade hog fuel boilers to increase hog firing	medium	medium	medium	medium	3.5.1
d new hog-fuel/recovery boilers	high	high	medium-long	medium	3.5.1, 3.5.4
3.3 Increase use of biomass in wood products industry	low-medium	medium-high	medium-long	medium	3.5.5
3.4 Increase use of other forms of renewable energy	low-medium	high	medium-long	medium	not presented
4 CHANGE PRODUCTION/CONSUMPTION PATTERNS AND STRUCTURE					
4.1 systems approach to energy use in the entire processing chain					
a rationalize timber location vs mill location to shorten transport distances	low	high	long	low	not presented
b optimize choice for new mill locations to reduce energy needs	low	high	long	low	not presented
c shift industry product mix to less energy-intensive products	low	high	long	low	not presented
4.2 life cycle approaches to compare net ghg emissions of wood and alternative products	medium-high	medium	medium-long	medium	not presented
B ENERGY OPTIONS - OTHER					
1 ENHANCE USE OF FOREST BIOMASS FOR BIOPOWER AND BIOFUELS					
1.8 Use biomass for electricity and space heating					
a small scale biopower	low-medium	medium-high	medium-long	medium	not presented
b large scale biopower	high	high	medium-long	medium-high	not presented
c district heating	low-medium	high	long	medium	not presented
d fuelwood use	low-medium	high	long	low-medium	not presented

Action		*A Priori* Assessment of Impact			Priority for Analysis	Status / Section in Report
		GHG Impact	Cost	Time Frame		
1.2	Use biomass for liquid biofuels					
	a ethanol	medium-high	high	medium-long	medium-high	3.7.2
	b other (methanol, biodiesel, pyrolysis oil)	low-medium	high	medium-long	medium-high	not presented
1.3	Hydrogen from biomass					not presented
	C DOMESTIC CARBON SEQUESTRATION OPTIONS					
1	**CURRENTLY ALLOWED BY THE PROTOCOL**					
1.1	Afforestation - increasing carbon sequestration from increased afforestation					
	a outside urban areas	high	high	medium-long	medium	4.2
	b urban forestry	low	high	medium-long	low-medium	not presented
1.2	Reforestation - increasing carbon sequestration by enhancing reforestation	?	low	medium-long	low-medium	4.3
1.3	Decrease deforestation	?	?	short-medium	medium	4.4
2	**NOT CURRENTLY IN THE PROTOCOL**					
2.1	Broadly-defined forest management activities					
	a fire protection	?	?	?	medium	4.5
	b pest/disease protection	?	?	?	medium	4.5
	c spacing	?	?	?	medium	4.5
	d thinning	?	?	?	medium	4.5
	e fertilization	?	?	?	medium	4.5
	f increased rotation age	?	?	?	medium	4.5
2.2	Carbon in forest products	?	?	?	low	4.5
	D COOPERATIVE IMPLEMENTATION OPTIONS					
1	**FOREST SECTOR PROJECTS IN OTHER COUNTRIES**					
1.1	Joint Implementation (JI)	high	?	medium	medium-high	not presented
1.2	Clean Development Mechanism (CDM)	high	?	medium	medium-high	not presented

GHG Impact (high, medium, low): A best guess relative qualitative assessment of the potential magnitude of ghg reductions in the first commitment period of 2008-2012 as a result of implementing the action, presumably around 2000/2001 (ie. relative to other Table actions). Implementation refers to putting in place policies/programs to promote the action (eg, tax changes, information programs, subsidies etc.).

Cost (high, medium, low): A best guess relative qualitative assessment of the total financial cost over time to achieve the ghg impact (ie. relative to other Table actions).

Time Frame (short, medium, long): A best guess qualitative assessment of how long it might take to see an appreciable ghg impact once an action has been implemented, presumably around 2000/2001. It is divided into short run (5 years), medium run (5-10 years) and long run (over 10 years). Implementation refers to putting in place policies/programs to promote an action (eg, tax changes, information programs, subsidies, etc.).

Priority (high, medium, low): Table members were asked to provide their assessment of the relative priority to attached to each action, based on a balancing of various considerations, including ghg impact, cost, potential to contribute to meeting Canada's target in the first commitment period and later periods, and degree of uncertainty.

Status/Chapter: Indicates where in the Options Report the action is discussed, or if the action was not subject to in-depth assessment.

In order to oversee the management and development of its research program, the Table created two subcommittees, the Energy and Technology Working Group and the "RAD" Working Group (RAD=reforestation, afforestation and deforestation - ie., the activities affecting forest carbon which are included in the Kyoto Protocol at present). The Energy and Technology Group was composed entirely of Forest Sector Table members and observers and had responsibility for research related to the energy options discussed in this Report. The RAD Working Group was composed of members of both the Forest Sector and Sinks Tables. The research program of the RAD Working Group served as the basis for both the carbon sequestration options presented in this Report as well as the forestry-related options included in the Sinks Table Options Report.

Wherever possible, the Table has tried to ensure that the options presented in this paper and the research that supports them conform to the analytical direction and guidelines provided to issue tables by the Climate Change Secretariat (CCS) and the Analysis and Modelling Group (AMG). Chapter 3.1 of this report provides an overview of the business-as-usual (BAU) baseline against which the Table was instructed to calculate mitigation potential of its energy-related actions while Chapter 3.2 outlines some of the key assumptions underlying the energy consumption actions in this paper. BAU baselines for RAD activities were estimated by the Table and are presented in Chapter 4.

1.1.2 Analytical Gaps and Directions for Further Research

The Forest Sector Table made every effort to fulfill its mandate in as comprehensive and objective a manner as possible. However, many actions identified in the Actions Matrix were not evaluated in sufficient detail by the Table to present as actions in this report. In most cases, these actions were not evaluated in the Table's research program because they were not identified as high priority items during the Table's priority-setting process. However, we would like to emphasize that this should not be interpreted to mean that these actions do not merit further study or that all members thought that they were unimportant. Many of these actions could make a significant contribution to ghg mitigation, particularly in the medium to longer term. We encourage any further work on ghg mitigation activities in the forest sector to give careful consideration to the actions on this list, particularly those that are not presented in Chapters 3 and 4 of this paper. In Chapter 5, we present some recommendations regarding future work on those actions which we did not assess, along with recommendations related to actions that we assessed.

Aside from being unable to evaluate the full range of possible actions, time and resource constraints also prevented us from fully addressing some key issues related to the Table's mandate. As well, many of the actions and policy directions presented in this document may require further evaluation and consultation prior to being implemented. Although the Table has tried to provide an analysis of the competitive, environmental and other non-ghg impacts of the actions presented in this paper, in many cases only a qualitative assessment has been possible. A more rigorous and empirical analysis of these impacts may be warranted in some cases. Despite the limitations of the analysis presented here, the Forest Sector Table believes that this report and the opportunities for ghg mitigation that it outlines form the basis of a strategy for the forest sector to make a substantial contribution toward reaching Canada's Kyoto target, one that is beyond its share in Canada's emissions.

1.2 LINKAGES WITH OTHER GROUPS

1.2.1 Linkages to Other Tables

There are large number of interfaces between the work and mandate of the Forest Sector Table and the activities of other issue tables. In order to ensure complementarity and maximize synergies between its work and that of other participants in the National Climate Change Process, the Forest Sector Table has established a number of linkages or partnerships with others involved in the process. Through its participation in such bodies as the Integrative Group and the Analysis and Modelling Group, the Table has tried to keep informed of and contribute to the development of the National Implementation Strategy as a whole.

In addition, the Table has maintained a number of formal or informal linkages with other issues tables. The strongest of these linkages has been to the Sinks Table. The two tables held a joint meeting in October, 1998 at which time the RAD Working Group with representation from both tables was established to oversee the development of a joint work program related to forest carbon sequestration options. The Forest Sector Table has also developed various linkages with other tables. One member of the Table served on the Industry Table which provided a linkage between the work of these two groups. In addition, the Forest Sector Table has maintained an ongoing dialogue with a number of other issue tables including the Buildings, Electricity, Enhanced Voluntary Action, Credit for Early Action, Transportation, Technology and Agriculture Tables. Despite these efforts to harmonize research activities wherever possible, the magnitude of the work, the short time frames and differing timetables for publication of Options Reports have made it difficult to fully coordinate the development of this Report with those of other issue tables.

1.2.2 Consultation Process

During the course of its work, the Forest Sector Table has actively sought the involvement of forest sector stakeholders in the National Climate Change Process in general and the work of the Forest Sector Table in particular. As part of this effort, the Table has tried to conduct its business in as open and transparent a fashion as possible. All of the Table's research reports are made available to stakeholders as they are finalized and many sector experts from outside of the Table process have been consulted on the design and development of these projects. Following the completion of its Foundation Paper in the fall of 1998, the Table distributed copies to hundreds of stakeholders across the country and invited their comments on it.

Both collectively and through the activities of its individual members, the Table has undertaken a number of initiatives to stimulate dialogue amongst sector stakeholders on issues relating to the Table's mandate. One means through which this has been done is by inviting interested stakeholders to join the Table as "second-tier" members. Second-tier Table members are sent all materials distributed to the Table but do not normally participate in Table meetings and conference calls. The Table's second-tier has over 30 members including at least one representative from every provincial and territorial government in Canada as well as representatives of industry groups and the environmental community. The Table has also briefed key stakeholder groups such as the Canadian Council of Forest Ministers (CCFM) and the Forest Sector Advisory Council (FSAC) on its progress on several occasions. In addition, many individual Table members have taken advantage of opportunities that have arisen for them to brief stakeholders on the climate change process or consult with them on the Table's work. Table members have also provided valuable linkages either formally or informally to other private or public sector bodies that are actively engaged in research and consultation efforts related to the forest sector and climate change.

The Table's stakeholder consultations also included more structured consultations with key stakeholder groups on its draft Options Report. In addition to distributing draft copies of this document to second-tier Table members and other stakeholders for comment, the Table also scheduled two separate consultative sessions to solicit input on a draft of the Options Report. One session was held with the Global Climate Change Task Force of the Canadian Pulp and Paper Association on June 17, 1999 while the other was held with representatives of the environmental community on June 21. The Table was briefed on both of these meetings and has tried to reflect some of the themes that emerged from these sessions in this document. Unfortunately, the severe time constraints facing the Forest Sector Table have prevented a broader and more detailed consultation from taking place. However, the Forest Sector Table views its work as the beginning of a process rather than the end and expects that interested parties will have other opportunities to input into the process as the National Implementation Strategy evolves.

2.0 FOREST SECTOR PERSPECTIVES

Given that forests and the products that emanate from them literally embody carbon, few segments of Canadian society are more intricately linked to the climate change issue and the implementation of the Kyoto Protocol than the forest sector. The forest industry is one of the major users of transportation services and is an important purchaser of electricity and chemicals. The sector's predominantly rural base and its status as Canada's largest non-urban employer add an additional challenge to dealing with the climate change issue. The industry's economic importance is matched by the significance of its energy use - it is the largest energy-consuming industrial sector in Canada - and it has substantial ghg emissions. Given that it exports over 70% of its output, the industry is particularly sensitive to changes in its competitive position.

In addition to industrial and competitiveness issues related to climate change and the forest sector, there are a number of issues relating to the forest resource itself. Canadian forests, particularly the boreal forest, could be altered in character and geographic location as a result of climate change. In addition, the fact that forests are recognized as carbon sinks and sources under the Kyoto Protocol creates a range of technical, economic and policy issues of importance to the sector.

While the many intersections between the forest sector and climate change give rise to a range of challenges in evaluating sector options related to Kyoto, they also create many opportunities. Because wood biomass is a renewable energy source, the CO_2 emissions associated its use are not included in a country's ghg inventory under international guidelines. Wood biomass is already the leading source of energy for the forest industry and this report presents a number of options for increasing the energy derived from this source, both for use within the forest sector and outside of it. The recognition of the carbon sequestration potential of forests under the Kyoto Protocol creates the potential for forestry activities to contribute to Canadian efforts to achieve our Kyoto target. In addition, there is a significant body of evidence to suggest that some forest products, particularly solid wood products used in construction applications, are considerably less greenhouse gas intensive on a life cycle basis than substitute materials.

Reflecting the importance of climate change and Kyoto to the forest sector, sector stakeholders have been pro-active in efforts to address climate change. Forest industry companies are well represented in emissions trading pilot projects and other voluntary initiatives related to climate change and the industry's direct ghg emissions have declined substantially from their 1990 levels. The forest sector is also actively engaged in the National Climate Change Process. In addition to the range of sector stakeholders represented on the Forest Sector and National Sinks Tables, forest industry experts sit on the Buildings, Industry, Credit for Early Action, Kyoto Mechanisms, and Enhanced Voluntary Action Issue Tables.

It is important to remember that Kyoto does not represent the starting point for Canada's response to climate change but rather a continuation of efforts that date back to at least the beginning of this decade. The industry views that recognition for the gains made thus far, through the development of baseline protection and credit for early action systems, is critical to ensuring the continued engagement of those who have taken a leadership role in addressing climate change. Within the broader forest sector, however, there are a range of views about whether credit for early action should be applied to specific actions that are part of the BAU projection.

Both the climate change phenomenon itself and Canada's national response to it pose significant risks to the long-term well being of the forest sector. However, the Table believes that, given a supportive policy environment and concerted action on the part of sector stakeholders, the sector can make a contribution toward reaching Kyoto that is disproportionate to its share of ghg emissions or economic activity while at the same time maintaining its long term health and vitality. Much can be done in the next 5-10 years, using proven technologies and methods. In time, even more may be possible as new and emerging technologies are developed and become widely available.

2.1 THE FOREST SECTOR AND ITS SITUATION

2.1.1 The Economic Significance of the Canadian Forest Industry

The forest products industry is Canada's leading manufacturing sector and a major economic force in all regions of the country, along with the logging and forestry services industries which provide its raw material. It accounts for 11% of Canada's manufacturing Gross Domestic Product (GDP) and provides jobs, directly and indirectly, to over 800,000 workers. With net exports of $32 billion in 1997, the forest industry is by far the largest contributor to Canada's trade balance. It has a significant presence in all regions of Canada and plays a crucial economic role in the economy of rural Canada. It also tends to be a very high wage industry with compensation levels well above the national average. The forest industry and its workers are also a major source of revenues for all levels of government - $9.3 billion in 1997 (Forest Sector Table, 1998).

Canada is the world's largest forest products exporter with $39 billion in exports representing approximately 18% of the global total in 1997 (FAO, 1999). While Canada sells its forest products to dozens of countries around the world, the US, Japan and the European Union together account for over 90% of the total. Given its export dependence, the forest sector needs to be able to compete on a delivered cost basis in key foreign markets with both local and other international rivals.

2.1.2 Aboriginal Peoples

Aboriginal people in Canada have a unique cultural and spiritual relationship with the land and many Aboriginal communities are dependant on the forest ecosystems to preserve their way of life. With most First-Nations and Métis communities located in forested areas, the forest industry is also a significant source of employment and business opportunities for Aboriginal peoples. Aboriginal people play a significant and growing role as stakeholders in Canada's forest sector and should be recognized as full partners in the development of Canada's National Implementation Strategy as it concerns the forest sector. The need for employment opportunities for a growing aboriginal labour force, land claim negotiations and settlements are among the numerous opportunities and issues closely linking aboriginal community development to the forest sector. In addition, changing perspectives on forest sustainability, certification, the protection of biodiversity and environmental values, climate change, the conduct of international trade and equity in the distribution of resources, are having a direct impact on the aspirations of Aboriginal peoples and their ability to derive a living from the land.

As with other stakeholders in the forest sector, climate change and the Kyoto Protocol give rise to a variety of uncertainties and challenges for Canada's Aboriginal peoples. Aboriginals are concerned about the long-term impacts that climate change may have on forests and their traditional way of life. As owners and employees of forest industry businesses, Aboriginal peoples share many of the concerns of other sector stakeholders related to the competitive implications of Kyoto implementation. However, the Kyoto Protocol and its domestic implementation may also create some opportunities for Canada's Aboriginal peoples. For example, many remote Aboriginal communities are not connected to natural gas pipelines or provincial power grids and often use fuel oil for their heating needs. Through the use of district heating systems powered by wood chip burning furnaces, these communities may be able to increase self-reliance and create economic opportunities locally while reducing greenhouse gas emissions (Conroy, 1998). District heating is a proven technology widely employed elsewhere in the world; over 250,000 homes in Sweden are heated by biofuel powered district heating systems (PriceWaterhouseCoopers, 1999). In addition, a number of the measures outlined in this paper, particularly afforestation programs, could create new economic opportunities for Aboriginal communities in Canada.

2.1.3 The Forest Industry and Rural Canada

While it is of national economic significance as a leading industrial sector, the forest industry is of special importance to rural Canada. The forest industry forms over half of the economic base of nearly 340 communities across the country which together are home to over 900,000 Canadians. Although concentrated in British Columbia, Quebec and Ontario, forest-dependent communities can be found in 9 provinces across Canada. While a number of larger centres are included in this group, most forest-dependent communities have populations of fewer than 5,000 people (Williamson and Samson, 1997). In many cases, a single company or mill forms the base of the community's economic life. In these communities, adjustment to mill closures or job losses can be particularly difficult as alternate economic opportunities often are limited.

The Forest Sector Table believes that significant action to reduce ghg emissions is possible within the sector without jeopardizing the future of the industry or the communities that depend upon it. A number of the measures presented in this paper could lead to the creation of new, high-skilled jobs in rural communities across the country. However, the Table also believes that a National Implementation Strategy needs to recognize the unique geography of the forest sector and be sensitive to the impact that even marginal changes in the circumstances of an individual mill sometimes can have.

2.1.4 Environmental Non-Governmental Organizations

Environmental Non-Governmental Organizations (ENGOs) in Canada have played a significant role in informing and influencing dialogue on forests and forest management. ENGOs are recognized as legitimate stakeholders in forest management decision-making at all scales, from the local to the international. Their contribution to stakeholder dialogue includes expertise on policy and practical issues, valuable local knowledge, and representation of a wide variety of public interests. Issues of particular interest to ENGOs include biodiversity and wildlife conservation, protected areas, water protection, local retention of forest-related benefits and certification programs.

There are currently more than one hundred local, regional or national ENGOs in Canada that devote considerable energies towards promoting and supporting improved forest management and several dozen ENGOs that work to influence policy and behaviour related to climate change. ENGOs with a particular focus on climate change are interested in ensuring that the measures explored by the Forest Sector Table are effective in mitigating climate change, and are supportive of efforts being considered by other sectors while ENGOs concerned mainly with forest issues want to be assured that proposed actions to mitigate climate change are consistent with sound forest management practices. There is an important role for these two groups of ENGOs in exploring areas of complementarity, as well as potential conflicts, between goals related to forest management and goals related to climate change. Two national networks, the Climate Action Network and the Forest Caucus of the Canadian Environmental Network, have mandates to support such learning and collaboration.

As noted earlier, the Forest Sector Table held a consultation session for a small group of representatives of the ENGO community from across Canada, including members from both the forest management and climate change communities, to review an early draft of the Options Report (Forsyth Consulting Essentials, 1999). While the ENGO representatives had not had an opportunity to fully review the draft report in detail, they did have some key impressions and conclusions, as summarized below.

The ENGO representatives consulted by the Table expressed a number of concerns related not only to the work and mandate of the Forest Sector Table, but also regarding the National Climate Change Process and the Kyoto Protocol itself. Some were concerned that the work of the Table related only to options to help meet Kyoto Protocol targets. As a result, they felt that the focus of the Table's work was not on the holistic approach of the Framework Convention on Climate Change (i.e., to protect and enhance ghg sinks and reservoirs and to limit anthropogenic ghg emissions), but on meeting what they see as the piecemeal, incompletely negotiated accounting mechanisms of the Kyoto Protocol. In addition, they were concerned that the focus of the work seemed to be more on carbon sequestration credits rather than reducing emissions. In general, there was a higher priority placed on options to reduce energy consumption and improve energy efficiency than on options related to carbon sequestration.

Some ENGO representatives indicated that they thought the research and background information prepared by the Table were insufficient, and identified a number of gaps in the Table's analysis. Others questioned the motivations of the Forest Sector Table and the overall Table process, suggesting that it is diversionary and intended to delay rather than facilitate action on climate change. In addition, participants suggested that the Forest Sector Table focussed too heavily on large scale forest industry operations, and did not adequately examine issues of concern to smaller scale producers. Some participants also took issue with the instructions provided to the Table which required that the mitigation potential of options be measured against a 'business as usual' baseline case. It was suggested that an approach whereby options were benchmarked against best available practices would have been more appropriate. In general, a fuller, more holistic analysis for the sector was recommended (e.g., inclusion of urban forestry, inclusion of ghg impacts of transportation and inputs such as fertilizers and pesticides for afforestation options).

2.1.5 Industry Financial Status and Ability to Invest

Historically, financial returns in the forest products industry have been highly cyclical. While the industry has enjoyed periods of strong profitability, it can also experience heavy losses during times of weak demand and prices. Overall, its financial performance of the past two decades has been lacklustre, relative to both other Canadian industries and some of its major foreign competitors. The industry's weak financial returns are reflected in the market valuations of the sector's assets. In many segments of the industry, production capacity can be purchased for far less than its "book value" or replacement cost. With an average return on capital employed of just 4 percent since 1989, the industry has not even come close to earning its cost of capital (Price Waterhouse Coopers, 1998a).

Canadian forest companies - both large and small - face significant challenges in attracting new investment capital. Increasingly, Canadian forest products companies find themselves under pressure from institutional investors and other shareholders to increase their financial returns. The industry's capital expenditures have historically been cyclical and highly correlated to financial performance. However, investors are increasingly demanding that firms minimize new capital investment. When firms are able to generate positive cash flows, they face pressure to distribute them to shareholders through dividends or to use them to retire debt. A rule of thumb is frequently applied by the financial community to the industry whereby capital investment by a firm in the industry is limited to its depreciation. From the point of view of investment to reduce ghg emissions, this is somewhat perverse, as older production facilities, where the potential for energy efficiency or other ghg reducing actions is often greatest, tend to be those where depreciation charges are the least.

As outlined in Chapter 3, the Forest Sector Table has identified a number of mill-level opportunities to lower direct or indirect sectoral emissions through fuel-switching or energy efficiency improvements. The Table believes that cumulatively, these actions could result in significant ghg reductions and many of these actions will generate significant cost savings through lower energy costs or other benefits. The difficulty lies in obtaining the financial resources needed to make large initial investments.

Some Table members believe that the industry's weak financial performance, and resulting difficulties in attracting capital, constitute a major impediment to action in further reducing its ghg emissions. This situation is compounded by the fact that a significant portion of the industry's tax burden is made up of profit insensitive taxes which tend to penalize the industry for its financial performance. Capital or other non-income sensitive taxes create a deterrent to investment in a capital intensive sector with relatively low financial returns like the forest industry. In 1997, the total tax burden for the industry based on total tax payments to government, excluding stumpage, represented 77 percent of pre-tax earnings (PriceWaterhouseCoopers, 1998b).

With capital for re-investment in its operations limited, the forest industry tends to apply very high hurdle rates to prospective investment projects (ERG/MK Jaccard & Associates, 1999; Bruce, 1999; CPPA, 1998). This is particularly true for fuel-switching or energy efficiency projects as firms tend to give priority to enhancements of core production activities over energy-saving projects when investment capital is scarce. One solution to this problem is the establishment of an "energy island" whereby an outside party - likely one with easier access to capital - invests in the project. While this type of arrangement may be suitable for certain types of projects, it may be impractical for many of the actions evaluated by the Table.

As discussed in Chapter 3, the Table believes an appropriate set of incentives for action could result in significant reduction in sectoral emissions in the near term. The Table believes that properly designed tax or other financial incentives for investments in fuel switching or energy efficiency projects offer a cost-effective means for quickly increasing uptake of ghg-reducing actions in the sector. While emissions trading or changes in economic conditions may eventually provide the necessary incentive for investment in many of these actions, these circumstances may take many years to materialize. Appropriate financial incentives provide the most effective short-term means of bringing expected returns from these capital expenditures closer to what the market judges to be a fair rate of return for these investments in the industry. The wide variability in regional, sectoral and mill-level circumstances, including fuel usage and capital availability, means that a flexible approach will be most cost-effective for reducing ghg emissions in the industry.

2.2 FOREST SECTOR AND KYOTO: ISSUES, OPPORTUNITIES AND CONCERNS

2.2.1 Kyoto and its Competitiveness Implications

Given its heavy export orientation, actions taken in Canada and abroad to deal with the climate change issue could have serious implications for the international competitiveness of the forest industry. In accordance with the direction provided to issue tables, the Forest Sector Table has tried wherever possible to identify and evaluate the competitive impacts of the options it has considered and presented. However, the Table could not provide a full assessment of the potential competitive impacts of the Kyoto Protocol on the Canadian forest sector in the time available to it. Ongoing international negotiations, the ratification and implementation of Kyoto by major trading partners and competitors as well as the development of Canada's own National Implementation Strategy are all key sources of uncertainty for the forest sector. These and other factors make it very difficult to empirically evaluate the competitive impacts of measures from a sectoral perspective. Analysis of the competitiveness implications of Kyoto implementation will continue during the development of a Kyoto implementation strategy. Forest sector stakeholders look forward to participating in the process.

While the Canadian forest industry has long been export-oriented, the industry is becoming increasingly globalized and several new entrants - Brazil, Indonesia, Chile and Malaysia - have begun to make significant in-roads into world markets. This phenomenon has been driven in part by technological advances in papermaking which have made it possible to substitute short fibre hardwood pulp from these regions for Canadian bleached softwood kraft pulp for most paper products (PriceWaterhouseCoopers, 1999). Yields from forests in equatorial and southern hemisphere regions are up to 20 times greater than in Canada (PriceWaterhouseCoopers, 1998a). With relatively low cost wood, energy and labour inputs, along with new and efficient manufacturing plants, these countries pose a serious challenge to Canada's export sales in both traditional and emerging markets.

In most cases, Canadian forest products firms operate as price takers on global markets with many other producers selling near or perfect substitutes to their products. This severely limits the scope for Canadian producers to pass on increased production costs to their customers. As a result, government policies which have the effect of increasing key input costs for forest products firms relative to those faced by their competitors could severely impact the competitive position of the forest industry.Clearly, whether Canada's major trading partners and competitors ratify Kyoto and their choice of policy instruments to meet their Kyoto commitments will have significant ramifications for the Canadian forest industry. Not only will these decisions influence the competitive position of Canadian producers relative to their home market competitors in export markets but they could also impact on final demand for forest products. For example, at least one analysis has suggested that the Canadian wood products industry could be adversely impacted by a dampening of construction activity in key export markets as a result of ghg mitigation policies (Standard & Poors-DRI, 1997).

The actions of Canada's major trading partners will have to be carefully considered both in assessing the competitive implications of Kyoto and in devising Canada's response to the Protocol. However, regardless of the actions taken by major trading partners in response to Kyoto, Canadian exporters face significant and growing competition in world markets from producers located in countries that have not yet agreed to emission limitation or reduction commitments under the Kyoto Protocol.

The potential impacts of Kyoto measures on the competitive position of the Canadian forest sector relative to rivals in the developing world need to be carefully considered in the development of an implementation strategy.

Although a mature industry facing a variety of challenges, the forest products industry remains a cornerstone of the Canadian economy. Global demand for forest products continues to grow steadily, as does the output of the Canadian forest industry. While output growth in the sector is coming increasingly from adding value or productivity improvements at existing facilities rather than investment in greenfield projects, some scope may exist for the development of new production facilities, particularly in segments of the wood products industry. Although subject to cyclical fluctuations, employment in the forest industry has been relatively stable over time, despite continuous increases in labour productivity. Total employment in the Canadian forest industry in 1998 was about 8 percent higher than it had been 20 years before (Statistics Canada, Cat. 71-201). Looking to the future, there is no reason to believe that the Canadian forest products industry cannot continue to be a major source of employment and economic opportunity for Canadians well into the next century.

2.2.2 The Forest Sector and Energy Policy

Canada's response to Kyoto has the potential to impact on the supply and price of virtually all of the forest industry's major purchased inputs including wood fibre, chemicals, transportation and energy. Of particular importance to the forest industry are potential changes to energy policy. While policy changes that result in higher energy prices could be detrimental to the industry's competitive position if corresponding price increases do not occur elsewhere, energy policy can also be used to encourage increased generation of renewable energy within the sector. Although the forest industry self-generates over half of its energy needs from renewable sources, it is also a large consumer of purchased electricity. The "indirect" emissions associated with generating this electricity are greater than the industry's direct emissions, despite the fact that a significant portion of the electricity generated in some provinces comes from zero emission sources such as hydro or nuclear energy.

The forest products industry is unique among major industrial energy consumers in that its production processes and by-products create the potential for the industry to generate renewable energy and virtually eliminate direct fossil fuel CO_2 emissions. Maximizing the energy generated from biofuels such as sawmill residues, other wood wastes, spent pulping liquor, and organic residues from effluent treatment creates a significant opportunity for the forest sector to contribute to reducing Canada's ghg emissions.

In addition to its production of lumber and wood chips for the pulp and paper industry, the sawmill sector in Canada generates approximately 18 million tonnes per year of sawdust, shavings and other wood residues. While a portion of this total has long been used as "hog fuel" for energy production or other purposes, a significant amount has traditionally been disposed of in landfills or incinerated as a waste product. However, the utilization rate for residues has increased from about 50 to 70% over the course of this decade as demand from both energy and non-energy uses have increased steadily (Hatton, 1999; Neufeld, 1999). While the geographic dispersion of the remaining residue surplus imposes practical limits on its use as an energy source, the Table believes that considerable scope exists to further increase the utilization rate. Significant concentrations of surplus wood wastes remain in regions of the country and Chapter 3 presents a number of measures to increase energy production from wood residues, both for use inside the sector and outside of it. These include wood waste cogeneration projects in both the wood and paper sectors, the production of ethanol for use as a transportation fuel and the modernization of hog fuel boilers in use within the pulp and paper sector. As wood residues become increasingly scarce and prices for them increase, other forms of biomass such as agricultural or municipal wastes and wood fibre from fast-growing energy plantations might be considered as alternative sources of biofuel.

In the pulp industry, mills with power boilers can meet some or all of their steam and electricity needs from low-emission renewable energy sources. In many cases, mills can generate substantial quantities of excess electricity. Although the forest industry has seen the share of its energy consumption generated from renewable sources increase substantially over the past two decades, the Forest Sector Table believes that considerably more is possible. While energy costs will typically amount to over $40 per tonne of product in most parts of Canada, Scandinavian producers have virtually eliminated this cost by becoming electrical energy self-sufficient (PriceWaterhouseCoopers, 1999). In

Finland, energy is a negative net cost for pulp producers as revenues from the sale of excess electricity into the grid exceed generation costs. In Canada, the availability of relatively low cost electricity combined with a restrictive regulatory environment in many provinces has prevented the development of a similar situation here. As outlined in Chapter 3, changes in electricity market regulation and pricing could contribute significantly to the increased production of wood waste cogenerated electricity, particularly if combined with a renewable energy policy like those in place in California and other US states, or as proposed federally in the US.

2.2.3 Environmental Issues

Driven by $5 billion in expenditures on pollution abatement and prevention technologies, the forest industry has improved its environmental performance considerably over the course of this decade. For example, through new investment in effluent treatment, chlorinated dioxins and furans have been virtually eliminated while other pollutants have been significantly reduced. The industry is currently making significant strides at reducing toxic chemical emissions from mill processes under the federal Accelerated Reduction/Elimination of Toxics (ARET) program.

Many of the actions presented in this report have significant environmental benefits in addition to their ghg mitigation potential. For example, afforestation on marginal agricultural land could improve soil and water quality, provide habitat for wildlife and increase biodiversity. Many of the energy options presented in Chapter 3 lower air or water emissions and reduce chemical use. However, some actions to reduce ghg emissions conflict with other environmental objectives. For example, the increased use of biomass fuel can result in increased emissions of fine particulate matter (PM), a substance for which more stringent standards are now being considered. The installation of technologies to control PM not only increase the cost of actions but also tend to increase energy consumption which can be counter productive from a climate change standpoint. Thus, in some cases, a tradeoff may exist between promoting ghg reducing actions and other environmental policies.

A particularly sensitive environmental issue in Canada revolves around the appropriateness of converting primary forests into managed second growth forests. Not surprisingly, there are diverse views on this issue among Table members. It is important to note that controversy around this issue is likely to be exacerbated in the course of international negotiations to clarify definitional uncertainties in the Kyoto Protocol, as well as in domestic discussions leading to an appropriate climate change strategy for Canada.

2.2.4 Life Cycle Considerations

In recent years, there has been growing interest in the use of Life Cycle Assessment (LCA) as a tool to assess the environmental performance, including the ghg impacts, of various products and services. Rather than simply focussing on a product's performance in its end-use application, LCA uses a holistic approach to measure the environmental impact of a product from raw material extraction through production and use to disposal. LCA models are being developed around the world for use in a wide range of applications. Reflecting the growing interest in LCA, a Technical Committee of the International Standards Organization (ISO) on LCA was established in 1993, with Canada as secretariat. Under the direction of this committee, a number of standards related to the application of LCA have been and are being developed.

As the single largest consumer of the earth's natural resources, there is no sector where LCA can make a greater contribution than in the building sector. Given the construction industry's status as the major end-use market for solid wood products, the forest industry, along with other suppliers of building materials, have jointly sponsored efforts to develop a Canadian LCA model for buildings. The Athena Sustainable Materials Institute, a Canadian not-for profit organization, has developed a model that allows comparisons of conceptual building designs in a life cycle framework. Work continues on refinements to Athena, including improved coverage of carbon cycle issues as well as considerations related to durability and the ultimate disposal of products. However, these ongoing efforts to expand the life cycle coverage of Athena are unlikely to reverse and may well reinforce the finding of this model that wood building design systems tend to use less energy and generate significantly fewer ghg emissions on a life-cycle basis than comparable structures using steel or concrete structural and building envelope components.

In addition to Athena, a number of other efforts are under way around the world to develop LCA models of the buildings sector. The Dutch government and building industry have agreed that LCA should be the basis for determining the environmental effects of building products. The government, in cooperation with private building sector stakeholders, has developed a software tool called Eco-Quantum that is very similar in function to the Athena model. Based on the findings of this model, Holland has already instituted policies that encourage the use of wood in many construction applications, despite the fact that Holland is heavily reliant on imported wood products. An effort is currently under way to more fully integrate LCA into the Dutch system of building codes and standards (Forintek Canada Corporation, 1999).

The Forest Sector Table believes that LCA is a potentially powerful policy and decision-making tool in the development of a National Implementation Strategy for Kyoto. Efforts to develop LCA tools and integrate them into decision-making processes should be supported by both public and private sector stakeholders. The Table also believes that any review of product standards - including building codes and standards - taken as part of the National Implementation Strategy should make use of LCA techniques wherever possible.

2.2.5 Emerging Technologies and Long Term Possibilities

The Forest Sector Table believes there are many actions within the sector that can be implemented rapidly to reduce sectoral emissions. In addition, there are a variety of emerging technologies discussed in Section 3.6 which could significantly increase the sector's capacity to reduce emissions. For example, there are a number of potential applications of gasification technologies within the sector that could allow mills to substantially increase their ability to generate energy from renewable sources. These technologies are a key area of energy-related research of the joint government-industry-academia Agenda 2020 for the pulp and paper industry in the US.

The Canadian forest sector is fortunate to have 3 world-class research institutes - Paprican, Forintek and Feric, to assist it in meeting its technology R&D, demonstration and commercialization needs. Although these organizations are involved in a range of activities, energy efficiency is a major focal point of their research efforts. Each of these not-for-profit organizations is funded through some combination of contracted research, contributions from member companies and government funding. As with other investment priorities in the sector, financial constraints have put pressure on R&D spending within the forest industry. In addition, government grants for forest sector R&D have often been reduced or replaced by repayable contributions. The Forest Sector Table believes that research and technology have a significant role to play in Canada's National Implementation Strategy. Not only can technology help to reduce emissions, but the development of ghg-friendly processes and technologies in Canada can also create new market opportunities for the forest sector and its suppliers. Both public and private sector stakeholders have a role to play in ensuring that climate change-related R&D in the forest sector is adequately funded.

One limitation to ghg reductions identified by the Table is the forest industry's risk-averse approach to new technology. The forest industry, and the pulp and paper sector in particular, is highly capital intensive. New technologies often entail very high capital costs and can have lifespans that can extend over decades. The financial situation of the industry, combined with the fact that technology decisions must often be lived with for years, mean that the industry is often very cautious with technologies that are not commercially proven. While there are few obvious policy solutions to this problem, innovative programs that serve to reduce or share the risks associated with adopting new technologies could serve to accelerate the penetration rate of ghg-mitigating technologies.

2.2.6 Voluntary Action

The forest industry has enjoyed considerable success in reducing its energy intensity and ghg emissions in recent years. Through efforts to raise awareness, disseminate information and document performance, voluntary initiatives have played a significant role in contributing to the industry's achievements to date. The Table believes that there is a continuing and perhaps strengthened role for voluntary institutions in addressing Canada's Kyoto commitments.

The forest industry is an active participant in the Canadian Industry Program for Energy Conservation (CIPEC) which has established sector task forces for both the wood and pulp and paper industries. CIPEC has recently published guides to energy saving opportunities for both the solid wood and kraft pulp sectors. In addition, 33 forest products companies are members of the Voluntary Challenge Registry (VCR), a not-for profit corporation that encourages voluntary initiatives to limit ghg emissions. Forest industry companies have also been active in emissions trading pilot projects like the Greenhouse Gas Emission Reduction Trading Pilot (GERT).

Some Table members believe that voluntary initiatives have a key role to play in the development of Canada's implementation strategy. The forest industry has demonstrated a clear commitment to voluntary institutions and has achieved considerable success in reducing emissions through voluntary initiatives - both formal and informal. Some Table members believe that voluntary actions - particularly if complemented by a supportive policy framework - can make a substantial contribution both toward further emission reductions and promoting carbon sequestration. Other Table members believe that voluntary initiatives are unlikely to be effective unless accompanied by a strong regulatory framework and well-designed appropriate financial incentives.

In the course of its work, the Table has examined many potential actions the sector could employ to reduce emissions through improved energy efficiency or fuel-switching. These range from simple actions like installing efficient lighting systems to investments that run into the tens of millions of dollars per mill. The Table has found that the cost effectiveness of each action varies considerably from one facility to the next and that no single action is appropriate in all cases. Factors such as a mill's age, product mix, technology stock, electricity supply and availability of wood residues among other factors play a key role in determining the feasibility of various actions at each mill. It is critical therefore that policies adopted in support of a National Implementation Strategy be flexible and encourage investment in actions where abatement costs are least. Decisions relating to how and where emissions reductions can be achieved are best made at the firm or mill level.

2.2.7 Credit for Early Action

Some members of the Forest Sector Table believes that the timely establishment of a fair and effective system of credit for early action should be a central element of a National Implementation Strategy. Such a system is seen as being critical to recognizing and thus maximizing the contributions possible from voluntary initiatives. It is also seen as being key to ensuring that actions toward reaching Kyoto are initiated rapidly.

Given the magnitude of the challenge facing Canada if it is to reach its Kyoto target, it is imperative that ghg mitigation action begin quickly, even though it may be several years before a comprehensive domestic or international policy framework is in place. However, in the absence of a system of credit for early action, uncertainty over future policy direction creates a deterrent to accelerated emission reductions. Entities that have undertaken early action risk not being credited or even penalized for doing so unless they are given some assurance that their actions will be recognized against any future obligation to reduce emissions.

In recognition of this problem, Joint Ministers of Energy and the Environment committed in April, 1998 to establishing a system of credit for early action by early 1999. However, the design of a system of credit for early action involves many complex and sometimes controversial issues, and agreement on the establishment of such a system had not yet been reached by the time the Forest Sector Table Options Report was finalized. Early in 1999, the Credit for Early Action Table put forward recommendations for the establishment of a system of baseline protection. This system is intended to reduce uncertainty by ensuring that entities that take early action are not disadvantaged by any future government policies that require a reduction in emissions relative to a baseline of historic emissions levels. While important, baseline protection is not nor is it intended to be a substitute for a full system of credit for early action.

The Forest Sector Table believes that the timely removal of uncertainties around systems of credit for early action and baseline protection are key to their potential contribution to a National Implementation Strategy.

2.2.8 Domestic Trading

The Forest Sector Table believes that voluntary action, particularly if combined with appropriate regulatory changes and incentives, can reduce the sector's emissions to well below their 1990 levels by the 2008-2012 period. However, the Table also realizes the same may not be true of other segments of the economy or society. In order to reach the Kyoto target, governments will likely have to employ a variety of policy instruments to achieve reductions in all sectors of the economy. One instrument that has attracted considerable attention in the context of Kyoto is domestic emissions trading. Certainly, there are strong theoretical reasons to believe that an emissions trading or a "tradeable permits" system offers the potential to achieve environmental goals more efficiently than conventional regulatory approaches. The Table believes that a National Implementation Strategy is most likely to achieve mitigation targets in a timely and cost-effective manner if it relies on broadly based market-oriented policy instruments and approaches, accompanied by effective regulatory frameworks and the removal of inappropriate incentives and disincentives.

2.2.9 Public Education and Outreach

The Forest Sector Table believes the sector can play a leading role in efforts to sensitize the public on climate change. The Table considers that some of the measures discussed in this report related to carbon sequestration could develop into unique opportunities to involve community groups across the country, particularly in rural Canada, in addressing climate change. In addition to contributing to greenhouse gas mitigation, afforestation or other sequestration activities could also contribute to the sensitization of rural communities, and Canadians in general, to climate change and the role that forests play as carbon sinks. These activities could be developed in part through community programmes and could be part of a long-term sensitization effort. Moreover, these activities would not be exclusive to the forest sector but could draw together partners from across the private, public and voluntary sectors. The target audience for such an exercise is not necessarily limited to rural communities. While the extent to which urban tree planting efforts will qualify for credit under Kyoto remains uncertain, such programs could still play an important role in public education and outreach efforts.

2.3 VIEWS ON INTERNATIONAL ISSUES

2.3.1 Kyoto Mechanisms and International Emissions Trading

The climate change problem is truly global in scope, both in its cause and effect. It has the potential to affect all countries of the world and all countries have a responsibility to contribute to a solution. A tonne of CO_2 or its equivalent has essentially the same impact on the global climate regardless of where on the planet it is emitted. Just as a domestic emissions trading offers the possibility of achieving environmental goals at lower costs than conventional regulatory approaches, so too does international trade in emissions credits. This is especially true for possible projects in the developing countries and economies in transition where the cost of reducing emissions may be much lower. High emission intensities in many sectors of developing economies mean that investments in these countries could achieve a greater environmental effect than a similar level of investment domestically. There may be a role for Canadian forest sector expertise in some of these projects.

The Kyoto Protocol introduced three international mechanisms to help make emissions reductions more cost-effective, known collectively as the international cooperative implementation or "Kyoto" mechanisms. Two of the mechanisms, the Clean Development Mechanism (CDM) and Joint Implementation (JI) are project-based. Considerable international work also is still needed to develop the rules for how these mechanisms will work and negotiations continue on the development of institutional structures for these mechanisms, project eligibility and monitoring, reporting and verification issues. While uncertainties remain regarding their scope, it seems clear that at least some forest-related carbon sequestration projects will qualify under these mechanisms.

With both emission reduction and carbon sequestration projects, the potential benefits that may be derived from Kyoto mechanisms will have to be weighed against possible competitiveness implications for Canada's forest industry. Given Canada's forest sector expertise, JI and CDM may create considerable opportunities to participate in international partnerships; however, heavy international investment in forestry projects through CDM and JI could have long-term

implications for global timber supply and prices. In addition, by allowing investors to take advantage of rapid carbon sequestration rates in many developing and some Annex 1 countries, these instruments could impact on the viability of afforestation or other sequestration projects in Canada.

2.3.2 Kyoto and Forests as Carbon Sinks and Sources

The recognition of the carbon sequestration potential of forests in the Protocol gives a unique opportunity for the forest sector to contribute to Canada's Kyoto response as well as representing a large source of uncertainty. Estimates of the impact of forest sinks and sources on Canada's ghg emission inventory in the first commitment period range from a large net carbon source to a significant net sink. A major uncertainty in estimating the impact of sinks relates to ongoing international negotiations; specifically, how the activities currently recognized under the Protocol (Reforestation, Afforestation and Deforestation - RAD) will be interpreted and what, if any, additional land use, land-use change and forestry activities may be included in the Protocol through future negotiations. Agreement on definitions may take as long as several years, which means that uncertainties about what can and cannot be included will likely continue for some time. Definitions of deforestation and reforestation will be important to determining their net impact on Canada's target in the first commitment period. Deforestation is counted as a source - i.e., it is added to Canada's target. Further work is needed to better establish current rates of deforestation as well as to determine policies or action needed to reduce current rates.

Assessing the sequestration potential and cost of various afforestation actions has been a major focus of the analytical program jointly undertaken by the Forest Sector and Sinks Issue Tables. Afforestation options differ from most other options assessed by Tables in that the benefits of a Canadian afforestation program would be relatively long-term in nature; while an afforestation program initiated in the next few years might make some contribution to offsetting Canada's ghg emissions in the 2008-2012 period, the full benefits of an afforestation program would not be realized until years or decades later. While there are high up-front costs, the average cost per tonne of CO_2 is very low in the long term, as trees grow to maturity over a 40 to 60 year time period.

The Protocol allows for discussion of additional direct human-induced activities in the agricultural soil and forestry categories that could be added to RAD. Many activities which affect the carbon balance of forests are not currently recognized in the Protocol. Forest management activities such as juvenile spacing and commercial thinning, fire protection, pest and disease control among others may all contribute to carbon sequestration. The Kyoto Protocol also does not consider the billions of tonnes of carbon currently stored in forest products. An important issue here for Canada - given its status as a large net exporter of forest products - is the definition of who is entitled to the credits for storage of carbon in forest products, the producer or the consumer.

2.4 CONCLUDING THOUGHTS AND PERSPECTIVES

The forest industry is proud of the leadership role it has played in addressing the climate change issue. The industry has been pro-active in voluntary efforts to reduce emissions and believes it has demonstrated that real results are possible through voluntary action. The Forest Sector Table believes that a supportive policy environment can allow the sector to make an even greater contribution toward reaching Kyoto in the future. While climate change is a long-term problem, the Table believes that early action is critical. Even with concerted early action from many sectors of society, the Kyoto target will be very difficult for Canada to reach; without it, the Kyoto target will quickly become virtually impossible.

Forest Sector Table members and sector stakeholders have a number of serious concerns related to both the evolution of the Kyoto Protocol internationally as well as its domestic implementation. However, the Table is confident that a domestic implementation strategy which is flexible and incentive-based can allow the sector to make a disproportionate contribution toward the Kyoto target without imposing an undue burden on any stakeholder groups. However, the Table also believes that a strategy which is inflexible or insensitive to the realities of the sector could cause serious harm not only to the industry and its employees but also to the country's balance of trade and the economy of rural Canada.

3.0 ENERGY OPTIONS ASSESSMENT

3.1 INTRODUCTION

This chapter outlines a range of actions that could be undertaken by the forest products industry to reduce both its direct and indirect ghg emissions either by reducing its energy intensity or by switching to less ghg-intensive fuel sources to meet its energy needs. It also identifies changes in government policies or other means that could be employed to realize the potential of these actions and assesses the non-ghg related implications of these actions and policy changes. The forest industry has already made significant strides in reducing its ghg intensity and is projected to continue to do so even in the absence of changes in relevant government policies. Although the forest industry's output is projected to increase by more than 40 percent over the 1990-2010 period in the BAU scenario presented below, direct ghg emissions are projected to decline by 3 percent and total emissions will grow by 15 percent. It should be noted that from a ghg inventory perspective, only direct ghg emissions are ascribed to the forest sector.

In accordance with the directions provided to sectoral issue tables by the Analysis and Modelling Group (AMG), the business-as-usual (BAU) projection outlined in the Natural Resources Canada (1997) publication *Canada's Energy Outlook 1996-2020*, and subsequently updated by the AMG, has been used to construct a baseline against which the ghg reduction potential of the actions presented in this chapter have been measured. The *Energy Outlook* and the update provide a projection of future Canadian energy demand under a BAU scenario in which federal and provincial energy, environment and related policies are held constant over the projection period, and energy prices generally remain constant in real terms.

The *Energy Outlook* projects end-use energy demand by fuel type for a number of major industrial sectors, including pulp, paper and lumber mills, and forestry operations. The revisions in the update reflect advice from the Table regarding future supplies of wood residues for use as energy in mills, as well as other changes such as revisions to projections of future industry growth. The updated projection was used to calculate the BAU baseline case for these mills' direct and indirect energy-related ghg emissions. The major segment missing from this projection is panelboard mills, and the Table sponsored a study of their BAU energy use and energy-related ghg emissions. Combined pulp, paper, lumber and panelboard mill energy-related ghg emissions are shown in Tables 3.1.1 and 3.1.2. These mills account for over 95 percent of total energy consumption in the forest products industry and their fuel use is representative of the industry as a whole. Within the forest products industry, the pulp and paper sector accounts for close to 90 percent of total energy consumption with the wood products industry accounting for the balance. Historical and projected emissions generated directly from the sector's operations are listed in Table 3.1.1. The indirect emissions associated with the industry's electricity purchases are shown in Table 3.1.2.

Table 3.1.1
Direct Forest Products Industry GHG Emissions
(Megatonnes CO_2e)

Region	1990	1997	2010
Atlantic	1.80	1.32	1.88
Quebec	4.40	4.13	4.02
Ontario	2.95	2.70	3.14
Manitoba	0.20	0.13	0.23
Saskatchewan	0.32	0.35	0.42
Alberta	0.35	0.69	0.95
British Columbia	3.75	2.87	2.76
Canada	13.78	12.18	13.41

The ghg reduction potential of the options presented in this paper have been calculated against a BAU scenario consistent with the one shown in these two Tables. Section 3.2 of this report provides a more detailed discussion of the assumptions and approach employed by the Table in developing its energy consumption options.

As shown in Table 3.1.1, the forest products industry has already made significant progress in reducing its direct ghg emissions. Between 1990 and 1997, the industry's direct emissions declined by over 10 percent despite significant increases in industry production over this period. These reductions are the result of both declines in the industry's energy intensity as well as increases in the proportion of the industry's energy needs derived from biomass. The use of biomass is considered to result in no net emissions of CO_2 when the biomass is derived from sustainably managed forests. Growth in the industry's use of biomass at the expense of fossil fuel has been under way for over 20 years and biofuels now account for over 50% of the industry's energy consumption. In the future, the sector's direct ghg emissions are projected to increase slightly between 1997 and 2010 but will still remain about 3% below their 1990 levels (Canada's target is a 6% reduction below the 1990 level).

Table 3.1.2
Indirect Forest Products Industry GHG Emissions
(Megatonnes CO_2e)

Region	1990	1997	2010
Atlantic	2.37	3.25	2.69
Quebec	0.00	0.00	0.00
Ontario	1.65	1.69	1.97
Manitoba	0.01	0.01	0.03
Saskatchewan	0.34	0.67	0.66
Alberta	1.59	3.33	3.25
British Columbia	0.33	0.35	1.09
Canada	6.30	9.29	9.69

Table 3.1.2 provides an estimate of the indirect ghg emissions attributable to the forest products industry through its purchases of electricity. These projections are for electricity purchases only and do not include indirect emissions associated with the industry's purchases of transportation services or other inputs. While indirect emissions are a significant proportion of the industry's national total, they vary widely across regions depending not only on electricity consumption but also the fuel mix used by utilities to generate electricity. For Quebec and Manitoba the assumption is that electricity purchased by mills is based on emissions-free hydro power. BC also uses predominantly hydropower though an increasing use of natural gas for electricity generation is expected to occur in the future. When direct and indirect emissions are combined, the BAU scenario suggests that the industry's total emissions increased by about 7 percent between 1990 and 1997. Total emissions are projected to be about 15 percent above the 1990 level in 2010, with a disproportionate share of the increase coming from lumber and especially panelboard mills.

3.2 FOREST INDUSTRY ENERGY OPTIONS - ANALYTICAL ISSUES AND KEY ASSUMPTIONS

3.2.1 Analytical Issues

Economic Analysis Versus Financial Analysis

Tables were instructed to assess the "lifetime" Net Present Value (NPV) of an action using a 10% real discount rate, where 'life' refers, for example, to the serviceable life of the new piece of equipment adopted as part of the action. This approach is meant to indicate the economic cost of each action using a consistent approach which allows comparisons across all actions assessed by all Tables. In general taxes are not taken into account since, from a broad societal perspective, taxes are simply a transfer from one group to another.

This economic cost approach differs from the financial analysis that is undertaken by forest industry companies to assess whether or not to invest in a project. Limited capital, high debt loads, a history of low returns, and large institutional shareholders who are demanding improved returns all mean that companies are extremely prudent when making investment decisions. These factors typically drive companies to seek a full payback on their investments in as little as two to four years, equivalent to *de facto* rates of return that are much higher than 10%. The reasons for this were explained more fully in Section 2.1.5.

Thus the use of a 10% rate tells us little about how forest industry companies look at the financial advisability of investments which could reduce ghg emissions, which is of relevance when considering what level of government incentive might be required to realize an action. To provide this perspective, which is different than that required for comparing actions across Tables, explicit accounting for the *de facto* rates of return sought by the industry must be done. In our analysis, we assume that the industry seeks a payback on its investments in 2 to 4 years and we use a pre-tax rate of return of 40% to capture this requirement. The after-tax rate of return would be lower.

In the action analyses, the lifetime NPV using a 10% discount rate is shown for each action (the net economic cost) and an indication of the action costs from the perspective of companies is also given (the net financial cost). Energy efficiency or fuel-switching investments typically involve a large initial capital outlay for equipment followed by a period of annual energy savings over the life of the equipment. After a few years the annual savings will have offset some portion of the initial capital investment. Projects for which the capital investment is completely offset after 2-4 years are those which the industry may typically fund, though other factors, such as the perceived riskiness of new technologies and the availability of capital, also play a crucial part in investment decisions.

Compared to using a 10% rate in the economic analysis, the NPV using a pre-tax 40% rate for the financial analysis substantially reduces the value of future costs and benefits compared to current costs and benefits, and it better represents the investment decision from the perspective of companies in the forest industry.

Estimation of Emission Impacts, Costs and Cost Effectiveness

The energy and technology actions analyzed by the Forest Sector Table represent opportunities to build upon the recent success of the pulp and paper industry in limiting its direct emissions. The forest products industry is expected to continue to build on this success and record a slight emission increase in 2010 compared to 1990, in a BAU world. The actions we analyzed represent opportunities to reduce both direct and indirect emissions to well below the 1990 level. We believe the assumed technology penetration rates used in the action analyses for the various efficient, fuel-switching and new or emerging technologies are feasible. We also believe that the actions will not occur in a BAU world over the next 10-15 years unless the appropriate incentives are put in place, and disincentives to action are removed.

The cost and emission impact estimates used in the analysis are measured on an incremental basis, relative to the BAU world. Thus the analysis typically is based on a comparison of choices that would be made in the BAU world during the normal capital replacement cycle in mills and potential alternative choices which would reduce ghg emissions. When the time comes to replace equipment a mill will have a choice of various technologies at various capital costs and with varying levels of energy efficiency. The incremental capital cost of choosing the more energy efficient (and usually more expensive) technology is the difference between its cost and the cost of the less energy efficient (and usually cheaper) technology. As the more energy efficient technology is used it will provide energy cost savings over time relative to the less energy efficient technology. It will also reduce emissions relative to the BAU technology choice. The cost effectiveness of the action is then the NPV of these incremental costs and savings (derived using a 10% discount rate) divided by the emission reductions over the serviceable life of the new machine put in place as a result of the action.

While the analytical guidelines issued to Tables ensure a consistent general approach to estimating costs and ghg emission impacts, there is still room for methodological differences which may affect the comparability of emission reductions, costs and cost effectiveness across actions. The Forest Sector Table used the guidelines but applied them in two somewhat different ways depending on the analytical approach used for specific actions. Some of our analysis was undertaken using the regional pulp and paper industry ISTUM simulation models of the Energy Research Group at Simon Fraser University. Additional detailed studies were done for specific actions in the wood industry, and for pulp and paper actions that were not included in the modelling work or were considered especially important.

In ISTUM, changes in technology, and the consequent changes in energy use and emissions, occur as capital investments in technology acquisition and use are made over the 2000-2010 period as mills need to replace equipment that has reached the end of its serviceable life. In contrast, in the stand-alone studies of certain specific actions, the analysis derives the ghg emissions impact and NPV of the incremental cost as if capital investment occurs all at once in 2000 (2005 or 2010 for new or emerging technologies). Thus this latter approach does not capture the dynamic investment behaviour that occurs over time, and that ISTUM models. For example, ISTUM takes into account the age profile of the existing stock of a given technology. Since a machine is only replaced at the end of its life, this means that the time profile of the investment needed to replace aging machinery is explicitly modelled.

The bulk of the analysis is based on the consultant studies listed in Annex A. However, the estimates in this report are not directly comparable to those in the consultants' studies, because of changes in assumptions or data after completion of the studies. In addition, some analysis was done internally based on information from Table members.

Evaluating Competitiveness, Economic and Social Impacts

It is very difficult to evaluate sector specific economic, social and competitiveness impacts due to the many uncertainties surrounding the implementation of climate change mitigation actions at home and abroad. This is certainly true in the case of the forest industry since the adoption of energy efficiency technologies will have positive and negative impacts on employment, industry costs, and sector competitiveness, both domestically and internationally.

We believe that the economic and competitive position of the forest industry (mostly the pulp and paper industry) could be improved by optimizing energy processes. However, evaluating the overall economic position of the Canadian forest industry against competing forestry nations, both those with and without Kyoto targets, is very complex and beyond the scope of much of the research undertaken by the Forest Sector Table, as it very much depends upon what actions are taken in those countries. Within each subsection of the discussion of energy options, a brief qualitative discussion is presented that outlines some of the key issues. However, more substantive and quantitative research in this area is required.

3.2.2 Key Assumptions

Energy Prices

The cost of the energy efficiency and fuel switching actions considered by the Forest Sector Table are very sensitive to assumptions about future energy prices - this represents a key uncertainty in the analysis. All Issue Tables have been instructed to use the energy price forecasts contained in *Canada's Energy Outlook 1996-2020* as the basis for their analysis. For wood residues (bark, sawdust and wood shavings), the Table used the assumption that the delivered price will remain constant in real terms at 1997$1.00 per gigajoule ($18 per oven dried tonne) for pulp and paper mills and 1997$0.56 per gigajoule (1997$10 per oven dried tonne) for wood industry mills.

Given the crucial importance of the energy price and related assumptions, the prices used in the analysis are shown in Table 3.2.1. Some Forest Sector Table members and other stakeholders have expressed reservations about some of these assumptions.

Though there are significant variations across the country in residue prices related to highly localized residue surpluses or shortages and environmental regulations which limit or prohibit incineration of wood wastes, there is insufficient information to derive regional average prices. Therefore, the above residue prices were assumed to apply to each province, while recognizing that this imposes a high degree of uncertainty in the inter-regional comparisons of costs and cost effectiveness.

Energy savings, total action costs, regional differences and differences between actions are all dependent on the prices of the various types of fuel in each region. Changes in the energy price assumptions can have significant effects on the estimated cost and cost effectiveness of each action, but the relative cost effectiveness of the various actions will be affected less.

Table 3.2.1
Key Assumptions Used in Analysis of Forest Industry
Energy Efficiency and Fuel Switching Actions

	Units	Atlantic	Quebec	Ontario	Prairies	BC
Wood residues						
Wood residue conversion factor	gigajoules / ODt	18	18	18	18	18
Residue price for pulp and paper mills, 2000	1997$ / gigajoule	1.00	1.00	1.00	1.00	1.00
Residue price for pulp and paper mills, 2005	1997$ / gigajoule	1.00	1.00	1.00	1.00	1.00
Residue price for pulp and paper mills, 2010	1997$ / gigajoule	1.00	1.00	1.00	1.00	1.00
Residue price for wood industry, 2000	1997$ / gigajoule	0.56	0.56	0.56	0.56	0.56
Residue price for wood industry, 2005	1997$ / gigajoule	0.56	0.56	0.56	0.56	0.56
Residue price for wood industry, 2010	1997$ / gigajoule	0.56	0.56	0.56	0.56	0.56
Wood residue boiler efficiency	%	65	65	65	65	65
Fossil fuels						
Marginal fossil fuel in mills		heavy oil	natural gas	natural gas	natural gas	natural gas
Emissions factor - CO_2, CH_4, N_2O	tonne / gigajoule	0.076	0.050	0.050	0.050	0.050
Fuel price, 2000	1997$ / gigajoule	4.03	4.22	3.45	2.02	1.73
Fuel price, 2005	1997$ / gigajoule	3.94	4.23	3.46	2.08	1.79
Fuel price, 2010	1997$ / gigajoule	3.9	4.25	3.49	2.14	1.85
Fossil fuel boiler efficiency	%	85	85	85	85	85
Purchased Electricity						
Price, 2000	1997$ / gigajoule	14.88	10.34	16.48	13.92	10.84
Price, 2005	1997$ / gigajoule	14.88	10.35	12.63	13.92	10.84
Price, 2010	1997$ / gigajoule	14.88	10.34	12.62	13.92	10.84
Price, 2000	1997 cents / kWh	5.36	3.72	5.93	5.01	3.90
Price, 2005	1997 cents / kWh	5.36	3.72	4.55	5.01	3.90
Price, 2010	1997 cents / kWh	5.36	3.72	4.54	5.01	3.90

Wood Residue Availability

The Forest Sector Table believes that fuel switching, especially from fossil fuels to biomass fuels, is a key approach to achieve significant ghg emission reductions in the forest industry. This potential is limited by the local availability of wood residues (bark, sawdust, wood shavings) and in a BAU world it is expected that increased use of wood residues in the pulp and paper and sawmilling industries will be relatively modest, as shown in Table 3.2.2. These estimates of BAU use of residues are consistent with those used in the update to *Canada's Energy Outlook*.

Table 3.2.2
Expected BAU Use of Wood Residues for Energy in the Pulp and Paper and Sawmill Industries

	Petajoules					Million Oven Dried Tonnes				
	1990	1995	2000	2005	2010	1990	1995	2000	2005	2010
Atlantic	19.3	26.1	25.6	25.6	25.6	1.07	1.45	1.42	1.42	1.42
Quebec	21.0	42.7	31.3	32.9	33.7	1.17	2.37	1.74	1.83	1.87
Ontario	12.6	21.1	24.1	24.1	24.1	0.70	1.17	1.34	1.34	1.34
Manitoba	1.7	1.8	2.1	2.1	2.1	0.09	0.10	0.12	0.12	0.12
Saskatchewan	1.6	1.9	1.8	1.8	1.8	0.09	0.11	0.10	0.10	0.10
Alberta	4.0	15.5	19.7	20.7	21.2	0.22	0.86	1.09	1.15	1.18
BC	38.7	57.9	43.3	47.6	50.0	2.15	3.22	2.41	2.65	2.78
Canada	**98.9**	**167.0**	**147.9**	**154.8**	**158.5**	**5.49**	**9.28**	**8.22**	**8.60**	**8.81**

The Table commissioned assessments of the current and future availability of surplus wood residues which potentially could be used for energy in the forest industry. These assessments are shown in Table 3.2.3. The Table's BAU projection of wood residue use is consistent with these estimates, which suggest a downward trend in the overall wood residue surplus, meaning that less and less surplus residue will be available to industry mills for use as energy. In part, a declining surplus reflects growing demand for residues for fibreboard, agricultural and other non-energy uses. Growth in interest in wood waste for electricity generation may also be important. At the same time, ongoing improvements in sawmilling and other technologies may reduce the amount of wood waste produced per unit of roundwood. Other biomass wastes, such as those from pulp mills and logging and sorting yards, or agricultural and municipal wastes, could help to offset the decline in wood residue surpluses. We did not assess these possibilities.

Table 3.2.3
Estimated Surplus Supply of Wood Residues

Province	Petajoules			Million Oven Dried Tonnes		
	1998	2000	2010	1998	2000	2010
Atlantic	4.7	3.8	1.6	0.26	0.21	0.09
Quebec	24.8	24.8	21.4	1.38	1.38	1.19
Ontario	8.1	4.7	2.3	0.45	0.26	0.13
Man.-Sask.	1.3	0.7	1.8	0.07	0.04	0.10
Alberta	16.2	12.1	0.7	0.90	0.67	0.04
BC	37.1	37.1	29.5	2.06	2.06	1.64
Canada	92.2	83.2	57.6	5.12	4.60	3.20

Increased use of wood waste energy in pulp mills will result from either the establishment of greenfield hog fuel boilers, conversion of existing fossil fuel boilers or incremental changes in hog fuel use through upgrading or replacement of existing boilers. The potential for each of these actions will depend largely on relative fuel and capital costs. For pulp mills, a major factor affecting future use of residues will be the availability of a sufficient and stable economic supply. Given current prices of fossil fuels, residues are typically a cost effective energy source only if they can be obtained within a 100 km radius. However, the residue surplus is scattered throughout the country and there are few areas at present where a large quantity of residues can be obtained economically within such a relatively small radius.

3.3 FOREST INDUSTRY ENERGY OPTIONS - IMPEDIMENTS AND POLICIES

3.3.1 Approach of the Forest Sector Table

In its work the Table focussed first on assessing the cost and ghg emission impact of specific actions. Once the action assessment was complete, we then focussed on identifying impediments to the actions, and a set of policies to overcome them. We did not consider just government policies but also looked at other means by which various stakeholders in the sector could facilitate efforts to reduce emissions. Both incentives and removal of disincentives were considered, as well as ways in which incentives could be provided (eg. tax expenditures, direct funding approaches, etc.

We found that a fairly small but important set of impediments act to prevent the forest industry from making the type of energy efficiency and fuel-switching investments which, among other things, would reduce ghg emissions. In our view, these impediments can be overcome with significant financial and other commitments from the industry, federal and provincial governments, other forest sector stakeholders, and other sectors, most notably the electrical utility sector. It must be emphasized, however, that further study of policies is needed to determine how to most cost effectively achieve implementation of the actions.

As a general principle, we believe new government initiatives should, where possible, build on existing policies and programs rather than create new ones. In some instances, removal of policies may be more appropriate. We also suggest that an approach which focusses on broadly applicable government policies and programs is likely to be less complex and more cost effective for both government and the forest industry than a set of narrowly targeted policies and programs. Broadly applicable approaches, or programs like those already in place in competing jurisdictions, would also be less subject to opposition and charges of subsidization by Canada's trading partners than would approaches targeted at specific sectors.

3.3.2 A Vision of the Future

A feasible future for the forest industry, and in particular pulp and paper mills, is as a highly modernized industry which is more competitive, produces far lower ghg emissions and is a net source of renewable energy to Canada. Indeed, newer mills in Canada and around the world already approach these goals.

Modernization has the potential to reduce ghg emissions very substantially. Estimates were prepared for the Forest Sector Table that show the potential impact of full modernization at Canada's kraft market pulp and newsprint mills on energy use and ghg emissions, and provide a benchmark for potential reductions. These two sectors account for almost 50 percent of Canadian pulp and paper production. Full modernization would involve the replacement of all major process and auxiliary machinery and equipment with the most energy efficient currently available. A fully modernized market kraft pulp mill would have direct and indirect energy-related ghg emissions that are as much as 90 percent lower than the current mill average. For newsprint mills, there is a direct link between the electricity input and newsprint quality and this creates some limits to the extent to which electricity inputs can be reduced. However, a reduction of about 75 percent below the current average ghg emission levels is still possible by reducing the fossil fuel used for steam generation. If all of these kraft and newsprint mills were to fully modernize the reductions could be on the order of 5-6 Mt CO_2e per year.

Rather than focussing on specific incremental actions, modernization of mills involves a wholesale replacement of older less efficient and more ghg-intensive technologies. In many cases it essentially would involve the construction of a greenfield mill in place of the existing mill. Full modernization is thus an expensive approach in terms of initial capital investment. However, in the longer term full scale modernization might be a cost-effective way to reduce the pulp and paper industry's ghg emissions, with the added very significant benefit of maintaining or enhancing competitiveness through reductions in production costs. Not surprisingly, the key impediment to modernization is lack of sufficient capital.

Modernization would permit Canada's pulp and paper mills to become a source of renewable energy. This would require efforts to reduce mill steam requirements (eg. partial system closure, thermal integration), improve energy efficiency, and build upon the industry's success in the 1990s in reducing fossil fuel use by switching to still greater use of wood residues as a fuel (fully modernized mills could obtain most of their energy needs from biomass fuels but, overall, would not require increased use of biomass). It also would require removal of impediments to the adoption of conventional cogeneration technologies, and the eventual adoption of emerging technologies such as integrated gasification combined cycle cogeneration. Together these changes mean that pulp and paper mills could produce more electricity from renewable biomass than they need, and the excess could then be sold and used to replace fossil-fuel generated electricity.

3.3.3 Key Impediments, Policies and Government Incentives

Impediments and Policies

To avoid repeating the discussion of identical impediments and policies for each action, this section summarizes the Table's assessment of the primary impediments and policies to overcome them, as shown in Table 3.3.1. In general, the impediments apply to most actions and many of the suggested policies and policy directions will help to create an overall policy environment which will encourage the industry to both modernize and achieve ghg emission reductions. Many of the policies shown in Table 3.3.1 do not apply only to the forest industry, but are much broader in their scope and therefore should be part of a broader policy approach in the National Implementation Strategy. The Forest Sector Table has identified seven key impediments.

1 **High hurdle rates.** The forest industry faces a number of factors which collectively result in high hurdle rates being applied to potential capital expenditures. Among the factors are limited resources, pronounced cyclicality in profits, a history of low returns coupled with a fundamental shift in shareholders toward greater ownership by large institutional investors who demand higher returns, and requirements to comply with current effluent and air pollution regulations. None of these are unique to the forest industry but they have the following impact on its investment behaviour:

- i energy efficiency projects face very high hurdle rates (pay backs of 1-3 years), in part because they are not 'core' to mill's focus, i.e., producing forest products;
- ii investments in core processes also face high hurdle rates (pay backs of as little as 3-5 years); and
- iii a growing interest in the concept of the 'energy island' which supplies energy to a mill and is under different ownership than the mill. This allows mills to focus on their core business of producing forest products and leaves energy supply issues to an energy company which often may face a much lower hurdle rate than the mill. Note that this means that ghg emission and energy issues related to production of energy for use by a mill would no longer fall within its management.

2 **Achieving more efficient energy use is not a high priority.** Energy costs are not a large part of costs except in certain segments of the forest products industry such as newsprint and some panelboards (and note that reducing energy use is not always the same as reducing ghg emissions in terms of complying with the Protocol - for example, reducing the use of biomass energy does not reduce CO_2 emissions). Coupled with high hurdle rates, this generally means that projects devoted only to changing energy use are seldom implemented. Of course, energy efficiency improvements and fuel-switching still happen, but generally as part of projects for improving production efficiency and product quality, or because companies need to dispose of residues.

3 **Lack of knowledge/information.** Mill managers may lack information on cost-saving opportunities

- i to improve energy efficiency through purchases of more efficient equipment,
- ii to improve energy efficiency through focus on energy systems, and
- iii associated with new and emerging technologies.

As well, there may be a lack of personnel at the mill level with a clear mandate to control energy use and an understanding of how to do so. On the other hand, considerable knowledge and information does exist and to some extent the problem is one of providing incentives to access the knowledge. If an incentive exists for energy efficiency then the knowledge and expertise that exists is more likely to be accessed.

4 **Risk averse approach to new technology.** The industry's financial situation, in conjunction with the fact that some technology decisions must be lived with for 20-40 years, means that the approach to new and emerging technologies is risk adverse. Early implementors of a new technology face particular problems.

5 **Promising technologies are not yet commercial, or are not applied in the Canadian industry.** Some potentially very useful technologies for ghg emission reduction are not yet at the commercial stage and need further work to resolve difficulties. Others may be applied in other industries or other countries, but have not been adopted in the forest industry in Canada. In part this reflects that difficulty the industry faces in raising capital for implementing proven technologies, let alone exploring emerging technologies. In comparison, Sweden, Finland and the US all have an industry-academic-government research, development and application efforts that exceed the effort in Canada.

6 **Structure of electricity markets.** Among other things, regulations, utility behaviour and economics limit or prevent the sale of excess electricity by pulp and paper mills, and this acts as a disincentive to any investments which produce excess electricity. Province-wide average electricity and transmission prices provide a disincentive to renewable energy and cogeneration initiatives by independent power producers. In the context of meeting Canada's Kyoto emission reduction target, we would like to emphasize that the supply of electricity should be looked at from a national or international perspective rather than a purely provincial point-of-view. In this respect, we believe that every savings on energy use or through fuel-switching should be seen as helping to reduce indirect emissions, even if it occurs in provinces dominated by hydro-electricity. Reductions in demand for hydro-electricity in one province mean that an equivalent amount of the hydro-electricity could be sold to provinces where electricity is generated using fossil fuels, if this were allowed.

7 **Lack of secure wood waste supply.** This impediment includes issues of a stable, sufficient supply at attractive delivered prices. Transportation costs are the major component of residue costs and a key barrier to greater use of existing residue surpluses in parts of Canada. There are other potential wood waste sources but these tend to be fairly costly to use due to poor quality and high transportation costs, or have not been explored to any great extent. These other potential sources include agricultural and municipal wastes (using these wastes is being explored by a few mills in Canada), waste biomass solids (primary and secondary effluent treatment sludges, and biomass from recycled paper), and logging and sorting yard wastes. Use of these wastes would require investment in equipment to improve quality (de-watering, sorting etc). Where transportation distances are increased, then the ghg emissions associated with the increased fossil fuel use from transport would have to balanced against the emission reductions from using the biomass. The Table did not assess these possibilities.

Direct Incentives to Realize the Actions

Each action typically involves an up-front incremental capital investment and a stream of annual net savings that result from the investment. We used this information in calculating the net economic and net financial costs for each action, as explained in Section 3.2.1.

As part of its work the Forest Sector Table has been asked to consider the level of incentive that would need to be provided to achieve the reductions estimated for each action described in this Chapter. This requires determining the total cost of the action and the proportion that the private sector could be expected to pay. Following the advice of the Analysis and Modelling Group, we used the net financial cost of an action (ie. its NPV using a pre-tax discount rate of 40%) as a measure of the incentive required to realize the action. Our approximation of the division of costs is based on the assumption that the private sector would be willing to pay that portion of the incremental capital costs which would be offset by discounted future energy saving, using the private sector hurdle rate. The remaining portion of the capital cost, which is the net financial cost, represents the value of the financial incentive needed to realize the action. In some cases, the Table's analysis suggests that an action provides a net savings, even when the pre-tax discount rate of 40% is used to calculate its NPV. In these cases we assume the direct incentive needed is zero.

Each actions analysis is done on a provincial/regional basis and summed to the national level. Where the net financial cost is positive in each province/region, the total direct incentive is the sum of the costs. Where the net financial cost is negative (ie. a savings) in each province/region, we show the total direct incentive as zero. In a few cases, some provinces/regions may have a positive net financial cost while others have a negative net financial cost.

In these cases, the total incentive is calculated as the sum of the positive financial costs. Provision of the incentive could occur in a wide variety of ways, which may or may not involve direct government funding, as suggested in Table 3.3.1.

Table 3.3.1
Impediments and Possible Policies to Encourage Energy Efficiency, Fuel Switching and Other GHG Emission-Reducing Actions in the Forest Industry

Impediments to Implementation	Potential Policies to Encourage Energy / Technology Actions
1 High hurdle rates	**1.1 Adjust the rules related to Class 43.1 accelerated capital cost allowance for investments in energy conservation and renewable energy equipment to allow greater use by pulp and paper and wood products mills, through widening applicability and / or increasing the depreciation rate, allowing unutilized deductions from Class 43.1 expenditures to flow-through to shareholders.** Responsibility: federal government Time frame: initiate in 2000 Cost: unknown tax expenditure, depends on use **1.2 Provide low interest or interest free loans for energy efficiency and renewable energy investments to be repaid directly through cash flow financing (ie. financed from energy bill savings)** Responsibility: federal government, provincial governments Time frame: initiate in 2000 Cost: zero **1.3 Provide tax credits to offset financial risks and reduce up-front costs of energy investments** Responsibility: federal government, provincial governments Time frame: initiate in 2000 Cost: unknown, depends on use **1.4 Provide rebates for certain types of energy-efficient auxiliary equipment (eg. motors, pumps)** Responsibility: federal government, provincial governments Time frame: initiate in 2000 Cost: unknown, depends on use **1.5 Remove or reduce sales tax on environmental equipment in a consistent way in all jurisdictions, and include wood reside cogeneration equipment** Responsibility: federal government, provincial governments Time frame: initiate in 2000 Cost: unknown, depends on use **1.6 Review capital taxes and non-revenue related taxes to assess how they can be adjusted to encourage higher levels of capital investment** Responsibility: federal government, provincial governments Time frame: initiate in 2000 Cost: unknown, depends on use **1.7 Allow expensing of investments in energy efficiency and fuel switching to encourage higher levels of capital investment** Responsibility: federal government, provincial governments Time frame: initiate in 2000 Cost: unknown, depends on use **1.8 Establish domestic emission trading systems and credit for early action, as appropriate, to provide incentives for and interest in energy conservation and fuel switching** Responsibility: federal government, provincial governments Time frame: initiate ASAP Cost: unknown
2 Energy efficiency not a high priority	**2.1 Establish domestic emission trading systems and credit for early action, as appropriate, to provide incentives for and interest in energy conservation and fuel switching** Responsibility: federal government, provincial governments Time frame: initiate ASAP Cost: unknown **2.2 Establish or increase ghg emission standards (as opposed to technology standards, which allow less flexibility and therefore are likely to be more costly)** Responsibility: federal government, provincial governments Time frame: ongoing Cost: unknown **2.3 Continuously update and strengthen Canada's Energy Efficiency Standards Regulation to regulate efficiency levels of imported equipment at increasingly higher, and cost effective, levels** Responsibility: federal government Time frame: ongoing Cost: unknown

Impediments to Implementation	Potential Policies to Encourage Energy / Technology Actions
3 Lack of knowledge/ information/ training	**3.1 Develop/implement workshops, guidebooks and technical training courses to provide information and transfer knowledge** Responsibility: Paprican and Pulp and Paper Technical Association of Canada (PAPTAC) in cooperation with federal government, research institutes and utilities Time frame: ongoing, with emphasis especially in 2000-2005 Cost: depends on action and uptake **3.2 Develop/implement workshops and information to show demonstration and pilot project results** Responsibility: federal government, research institutes Time frame: ongoing Cost: depends on action **3.3 Provide funding for mill energy audits, ghg emission reduction feasibility studies, and demonstration projects, with commitment by all parties to follow-up** Responsibility: Lead by industry research institutes with support from mills and engineering community, industry associations, federal government and provincial governments Time frame: ongoing Cost: depends on uptake and project **3.4 Undertake mill-level projects to identify and implement process thermal integration opportunities (eg., pinch analysis studies, implement select projects)** Responsibility: Mills, Paprican, PAPTAC, engineering community, utilities coordinated by federal government Timeframe: 2000-2005 Cost: about $20 million for case studies and implementation at 10 mills **3.5 Provide technical assistance and extension services to help in-house identification and implementation of energy efficiency and fuel switching projects** Responsibility: federal government, provincial governments, research institutes, industry associations Time frame: ongoing Cost: depends on uptake **3.6 Sponsor apprenticeship or mentoring programs in mills and engineering consulting firms (both students and people already in the industry) to support development of trained personnel with a strong background in energy use issues** Responsibility: federal government, provincial governments, research institutes, industry associations Time frame: ongoing Cost: depends on uptake **3.7 Support a sector training council that delivers, on behalf of the industry, energy training courses and information.** Responsibility: industry associations, mills, federal government, provincial governments, research institutes Time frame: ongoing Cost: depends on uptake
4 Risk averse approach to new technology	**4.1 Adjust the rules related to Class 43.1 accelerated capital cost allowance for investments in energy conservation and renewable energy equipment to allow greater use by pulp and paper and wood products mills, through widening applicability and / or increasing the depreciation rate, allowing unutilized deductions from Class 43. 1 expenditures to flow-through to shareholders.** Responsibility: federal government Time frame: initiate in 2000 Cost: unknown tax expenditure, depends on use **4.2 Provide tax credits/subsidies to offset financial risks and reduce up-front costs of investments** Responsibility: federal government, provincial governments Time frame: initiate in 2000 Cost: unknown, depends on uptake **4.3 Expand information and extension services available to the industry regarding experiences in development and use of new technologies, including in other industries and other countries, especially Scandinavia** Responsibility: Paprican, Forintek, FERIC, supported by federal government provincial governments, industry and engineering community Time frame: initiate in 2000 Cost: unknown, depends on uptake

Impediments to Implementation	Potential Policies to Encourage Energy / Technology Actions
5 Promising technologies not yet commercial, or not yet applied in the industry	**5.1 Use technology development, technology commercialization and market research policies to accelerate commercialization by addressing technical issues and promoting market development** Responsibility: federal and provincial governments, research institutes, academia, with industry support Time frame: initiate Cost: depends on action **5.2 Provide support for pilot and showcase projects** Responsibility: projects led by research institutes in conjunction with mill partners and with support from federal and provincial governments Time frame: initiate in 2000 Cost: depends on action **5.3 Increase support for shared-funding research in energy use in the forest industry** Responsibility: provincial and federal governments, industry, research institutes Time frame: initiate in 2000 Cost: depends on action **5.4 Expand information and extension services available to the industry regarding experiences in development and use of new technologies, including in other industries and other countries, especially Scandinavia** Responsibility: Paprican, Forintek, FERIC, supported by federal government provincial governments, industry and engineering community Time frame: initiate in 2000 Cost: unknown, depends on uptake
6 Structure of electricity markets	**6.1 Link and strengthen provincial advocacy groups for non-utility generators (NUGs)** Responsibility: forest and other non-utility generators Time frame: initiate 2000 Cost: unknown **6.2 Change utility industry regulation to encourage/allow sale by mills of excess electricity and standardize regulatory treatment of NUGs** Responsibility: provincial governments Time frame: by 2000 Cost: unknown **6.3 Establish tools/methods to quantify economic and environmental benefits of non-utility generation and ensure it is given fair treatment in policies related power generation** Responsibility: provincial governments, federal government, NUGs Time frame: initiate 2000 Cost: unknown **6.4 Establish renewable energy policy which requires a minimum contribution of renewable energy to the power pool (a renewable set-aside)** Responsibility: provincial governments, federal government(?) Time frame: by 2000 Cost: unknown **6.5 Change utility regulations to encourage/allow regional differentiation of electricity rates to reflect local and seasonal marginal costs of transmission, so as to provide a clearer incentive for renewable energy and cogeneration initiatives in remote and higher cost areas.** Responsibility: provincial governments Time frame: by 2005 Cost: unknown
7 Lack of secure wood waste supply	**7.1 Policies to facilitate increased use of tree spacing and thinning waste, logging wastes and sorting yard wastes (eg. subsidies, regulation etc)** Responsibility: provincial governments Time frame: by 2005 Cost: unknown **7.2 Policies to support development of renewable biomass energy, potentially including rapid growth plantations for fuel (see Chapter 4 on afforestation policies)** Responsibility: federal, provincial governments, industry associations Time frame: initiate in 2000 Cost: unknown, depends on afforestation costs

It is important to understand what our estimated "incentives for realization" measure. They measure only the value of the incentive required to make an action practically feasible. This could be in the form of a direct or indirect financial incentive, or some other policy measure that has an equivalent value. A calculated incentive of zero for a particular action in a given province/region should not be construed as suggesting that government incentives are not needed to achieve the action. Nor does the calculated level of incentive necessarily represent the full level of government assistance required. What the analysis suggests in cases where a net financial saving would result is that there are many actions which could be of benefit to the industry by reducing production costs, and which would also reduce ghg emissions, but which are not being implemented currently (and will not be implemented in a BAU world) for a variety of reasons. As already noted, these reasons include a lack of capital, the riskiness of making large investments in developing and implementing emerging technologies, a need to focus the limited capital available on improving core production processes rather than energy saving or fuel-switching, and perhaps in some cases a lack of information. In such cases, the role of governments interested in reducing ghg emissions is to address the impediments created by limited capital, risk and lack of information. This is in addition to the need to make the actions financially feasible. Note that addressing the problem of limited capital will tend to lower the *de facto* hurdle rate used by companies and will serve to help reduce the estimated net financial cost of actions, because a lower discount rate would be used.

As well, there are at least two other key ways in which industry investments which reduce ghg emissions could be promoted by providing financial benefits that would make the investments more attractive. One applies to the situation in which a mill could generate excess electricity. As already discussed, being able to sell the excess could create a powerful incentive. A second way to create financial benefits is through an emissions trading framework which creates value for emission reduction 'products'.

3.4 FOREST INDUSTRY ENERGY OPTIONS - ACTIONS TO IMPROVE ENERGY EFFICIENCY

These actions result in reductions in energy use through the adoption over time of more energy efficient technologies or through better use of existing equipment, whether through improved maintenance or through taking a systems approach to energy flows in mills. The actions assessed by the Forest Sector Table are summarized in Table 3.4.1. Note that the impacts of these actions are not necessarily additive.

Table 3.4.1
Summary of Forest Industry Energy Efficiency Actions

Action	Net Economic Cost[1] 1997$ million	Cost Effectiveness[1] 1997$ / t CO_2e	GHG Emission Reduction 2010 Mt CO_2e	Estimated Incentive for Realization[2] 1997$ mil
1. Improve process thermal integration - pulp and paper mills	-596	-31.8	1.25	0
2. Adopt energy efficient process technologies - pulp and paper mills	-1719	-24.1	2.68	839
3. Improve maintenance and use of existing auxiliary equipment - pulp and paper mills	-233	-64.1	0.36	0
4. Improve maintenance and use of existing steam-producing equipment - pulp and paper mills	-522	-61.3	0.85	0
5. Adopt high energy-efficiency auxiliary technologies - pulp and paper mills	-996	-90.8	0.65	0
6. Adopt high energy-efficiency technologies - lumber and panelboard mills	29	4.4	0.33	57

Note: Negative costs represent a saving.

1 Cost effectiveness and net economic cost derived using a 10% discount rate. Cost effectiveness is the NPV of an action (using the 10% rate) divided by the emission reductions over the 'life' of the investment (eg. the serviceable life of a new machine).

2 As defined in Section 3.3.3, the incentive to realize an action is based on the net financial cost of the action (NPV using a pre-tax 40% discount rate). An incentive of zero is shown where the action has net savings in each province/region.

The results include direct and indirect CO_2, CH_4 and N_2O emission reductions. Indirect emission reductions are based on the assumption that the marginal source of electricity in BC and Quebec is hydropower. If the marginal source in these provinces is from natural gas then national emission reductions and cost effectiveness are higher. All of the emission reductions for process thermal integration (action 1) and improved use of pulp and paper steam-producing equipment (action 4) are direct reductions and result from less use of fossil fuel and lower CH_4 and N_2O emissions due to less use of biomass fuel. All of the reductions for the two pulp and paper actions related to auxiliary technologies (actions 3 and 5) are indirect reductions and reflect reduced purchases of electricity. The remaining two actions are a combination of direct and indirect emission reductions.

3.4.1 Action: Improved Process Thermal Integration in Pulp and Paper Mills

ACTION:	***Reduce total energy use in pulp and paper mills by 6% through improved mill-wide process thermal integration***

Systems approaches look at the efficiency of the entire energy use system rather than the efficiency of individual components. One aspect of this approach in pulp and paper mills is optimization of the transfer of heat between various mill processes (process thermal integration). Such optimization reduces the need for production of heat, which translates into lower boiler fuel consumption and less greenhouse gases if the fuel reduced is fossil fuel.

A number of studies of mills in Canada, the US and elsewhere have identified potential projects which could reduce energy use through improved process thermal integration. However, there has been little follow-up of these studies to identify the proportion of projects that are actually implemented. Proposed projects vary from mill to mill, reflecting mill set-up and operation characteristics. Using 1997 data, an 8% reduction in the net heat energy (ie adjusted for boiler efficiencies) required for mill processes is estimated to be possible in Canada. This is equivalent to a reduction of about 6% in total energy use in all mills. This energy saving is derived from many small, mill specific and often technically complex projects. For the type of non-essential energy-savings projects being considered here, mills generally require a payback period of about 2 years.

The cost analysis in Table 3.4.2 is based on a top-down assessment of the energy reduction impact of projects which are assumed to be economic from the perspective of the pulp and paper mills. To reflect the current and expected future financial constraints facing the industry, as discussed in Section 2.1, "economic" was assumed to mean a payback of 2-3 years for energy efficiency projects. However, this does not mean that, in fact, mills will undertake such projects given limited access to capital and other impediments.

Table 3.4.2
Action Costs and GHG Impacts of Thermal Process Energy Reduction

	Estimate	Assumptions
Lifetime	15 years	
GHG impact		
lifetime ghg reduction	18.7 Mt CO_2e direct	all projects implemented in 2000-2005, which is considered a very fast but feasible time in which to identify and implement
ghg reduction 2010	1.25 Mt CO_2e direct	
Incremental cost (1997$)		
capital	$ 197.5 million	
O&M	$ 4.0 million / yr	2% of capital costs
fuel	- $ 98.8 million / yr	7.8% reduction in process energy; uses energy prices in 2000
Net economic cost		
lifetime NPV (1997$)	- $ 595.8 million	using 10% discount rate
lifetime 1997$ /tonne	- $ 31.8/t CO_2e	
Net financial cost		
lifetime NPV (1997$)	- $ 132.2 million	using pre-tax 40% discount rate

Note: a negative cost indicates a net savings. For net financial cost, a positive value represents the amount that would be required to make the action financially feasible from the industry perspective. A project may be financially feasible but not go ahead because considerations other than financial return also influence investment behaviour (eg. capital availability, risk).

Table 3.4.3
Regional Implications of Thermal Process Energy Reduction

Region	% Share in Industry Production	Annual Wood Residue Saving mill ODt/yr	Annual Fossil Fuel Saving PJ/yr	GHG Reduction in 2010 Mt CO_2e	Net Economic Cost (10% discount rate) 1997$ mill	Cost Effectiveness 1997$ / Mt CO_2e	Net Financial Cost (40% discount rate) 1997$ mill
Atlantic	13	0.22	2.30	0.15	-79.2	-36.1	-17.6
Quebec	34	0.28	5.80	0.34	-178.1	-34.4	-39.5
Ontario	20	0.23	6.28	0.28	-155.4	-36.8	-34.5
Prairies	10	0.18	1.91	0.11	-43.2	-25.6	-9.6
BC	23	0.66	6.57	0.36	-139.9	-25.7	-31.0
Canada	100	1.57	22.85	1.25	-595.8	-31.8	-132.2

Note: negative values represent net savings.

Knowledge/information on the potential benefits of a systems approach to optimizing energy management is scarce. For example, there is only one Canadian engineering school focussing on thermal integration in the forest sector and only a few Canadian engineering firms are experienced in forest sector thermal integration. Policies to overcome this lack will be required. As well, energy integration is best accomplished during modernization projects involving segments or all of a mill. Thus, as a general policy direction, incentives to encourage modernization of mills need to be considered

Table 3.4.4
Intra-Sectoral Implications of Thermal Process Energy Reduction

Mill Type	% Share in Industry Production	GHG Reduction in 2010 Mt CO_2	% Process Energy Reduction	Annual Fuel Cost Saving 1997$mill	Capital Investment 1997$mill
Chemical pulp	24	0.43	7	31	61
Integrated chemical pulp & paper	14	0.27	7	21	41
Newsprint with chemical pulp	19	0.25	13	25	50
Other newsprint	20	0.13	9	11	23
All other	23	0.16	5	11	23
Total	100	1.25	8	99	198

Note: negative values represent net savings.

3.4.2 Action: Adopt High Energy-Efficiency Process Technologies in the Pulp and Paper Industry

ACTION:	***All process-specific technologies purchased in 2000 to 2010 in the pulp and paper industry are at least efficient as the most efficient technologies currently available***

This action is based on analysis using ISTUM. The technologies being considered here are those which are specific to the pulp and paper industry. They include pulp digesters, chemical recovery boilers, lime kilns and evaporators used in the production of chemical pulp; refiners and grinders used to produce mechanical pulp; and various technologies for paper stock preparation and paper drying, refining and forming. Process technologies such as these account for roughly 55-65% of the pulp and paper industry's end-use energy consumption so that considerable scope can exist to reduce emissions, both directly, and indirectly through reductions in electricity purchases.

This action assumes that when any equipment reaches the end of its serviceable life, it is replaced with a technology which minimizes ghg emissions. In general, this usually will mean that the most energy efficient technology is purchased, though this need not be the case. Investment in new process machinery to replace old machines also occurs to satisfy demand growth. The penetration of the high efficiency technologies rises over time and is a function of the current age of the technology stock and the rate of growth in demand.

Table 3.4.5
Action Costs and GHG Impacts of Using High Energy-Efficiency Process Technologies in the Pulp and Paper Industry

	Estimate	Assumptions
Lifetime	20 -30 years	the life of most technologies is 20 years
GHG impact		
lifetime ghg reduction	71.4 Mt CO_2e direct and indirect	results derived using ISTUM: marginal fuel for electricity in BC and Quebec is hydro up to 2012
ghg reduction 2010	2.68 Mt CO_2e direct and indirect	
Incremental cost (1997$)		
capital	$ 919.5 million	O&M and fuel savings is an annual average: actual savings vary over time depending on the time-path of the investment, which depends on the age of the existing technology stock
O&M and fuel	- $ 254.5 / yr	
Net economic cost		
lifetime NPV (1997$)	- $ 1,719.3 million	using 10% discount rate
lifetime 1997$ /tonne	- $ 24.1 / t CO_2e	
Net financial cost		
lifetime NPV (1997$)	$ 3.8 million	using a pre-tax 40% discount rate

Note: a negative cost indicates a net savings. For net financial cost, a positive value represents the amount that would be required to make the action financially feasible from the industry perspective. A project may be financially feasible but not go ahead because considerations other than financial return also influence investment behaviour (eg. capital availability, risk).

Table 3.4.6
Regional Implications of Using High Energy-Efficiency Process Technologies in the Pulp and Paper Industry

Region	% Share in Industry Production	GHG Reduction in 2010 Mt CO_2e	Net Economic Cost (10% discount rate) 1997$ mill	Cost Effectiveness 1997$ / Mt CO_2e	Net Financial Cost (40% discount rate) 1997$ million
Atlantic	12	0.29	-98.1	-15.6	19.3
Quebec	35	0.75	-483.3	-26.3	215.8
Ontario	21	1.05	-365.5	-13.4	29.4
Alberta	7	0.26	-264.3	-49	-95.5
BC	25	0.32	-508	-35.9	-165.3
Total	100	2.68	-1719.3	-24.1	3.8

Note: Manitoba/Saskatchewan not included in the analysis because of the small size of their industries. Negative values represent net savings.

The large regional variations shown in Table 3.4.6 are determined by a variety of factors. These include differences in: the age of the process technology stock, with Eastern Canada typically having a somewhat older stock; the mix of pulp and paper products produced; whether or not there are significant indirect emissions reductions, with BC and Quebec having less indirect emission reductions because of the assumption that the marginal source of electricity is hydropower up to 2012; and the fuels used to produce steam, with a higher use of fossil fuels as opposed to wood residues in Ontario. If BC and Quebec are assumed instead to use natural gas as the marginal source of electricity, then this action results in additional emission reductions of 1.1 Mt CO_2e, split evenly between BC and Quebec. Most of the indirect emission reductions result from changes in mechanical pulping technology, since these processes tend to use the most electricity.

The chemical pulp, mechanical pulp and paper sectors of the industry provide roughly equal ghg emission reductions in 2010 from this action. Note, however, that the cost and cost effectiveness of the action in each sector vary considerably. In the pulp sector, large net economic and financial savings occur while in the paper sector there are large net economic and financial costs.

Table 3.4.7
Intra-Sectoral Implications of Using High Energy-Efficiency Process Technologies in the Pulp and Paper Industry

Process Type	GHG Reduction in 2010 Mt CO_2e	Net Economic Cost (10% discount rate) 1997$ mill	Cost Effectiveness 1997$ / Mt CO_2e	Net Financial Cost (40% discount rate) 1997$ million
Chemical pulp	0.95	-1058.4	-42.6	-502.8
Mechanical pulp	0.9	-1234	-50.6	-332.8
Paper	0.84	573.1	25.8	839.3
Total	2.68	-1719.3	-24.1	3.8

Note: negative values represent net savings.

3.4.3 Action: Adopt Improved Maintenance and Use of Existing Pulp and Paper Mill Auxiliary Equipment

ACTION:	***Adjust maintenance and use of pulp and paper mill auxiliary equipment to achieve best-practice maintenance and operation in all mills***

This action is based on analysis using ISTUM. Auxiliary technologies include generic pumps, fans, compressors, conveyors and motors. As such they are not specific to the pulp and paper industry. We assume that in the business-as-usual world the future levels of maintenance and the way in which equipment is used remains unchanged from the current level. For this action we assume that in 2000 all mills implement a best-practice approach to maintenance and use of their existing equipment, including appropriate sizing and technology to accomplish a given task and appropriate use such as turning off equipment when it is not in use. Thus this action does not involve purchases of new equipment but instead requires investing in better use of existing equipment.

The range of possible activities covered by this action is wide and individually they will have uncertain and mill-specific effects. We assume that collectively these actions will improve energy efficiency by between 2% and 15%, depending on the type of auxiliary technology. We also assume that operating and maintenance costs will increase by 10% to reflect the increased effort needed to achieve the more efficient use.

These auxiliary technologies account for roughly 15-20% of the pulp and paper industry's end-use energy consumption so that improvements in the efficiency of use of up to 15% could reduce mill energy requirements by up to 2%. As these technologies use electricity, all of the emission reductions occur via reductions in purchased electricity, which reduces energy costs for mills. This saving is partially offset by increased maintenance costs. Overall, the net effect is a reduction in costs relative to the business-as-usual situation.

Table 3.4.8
Action Costs and GHG Impacts of Improved Maintenance and Use of Pulp and Paper Industry Auxiliary Technologies

	Estimate	Assumptions
Lifetime	5 -30 years	depends on the age of the technology stock when improved maintenance is implemented - the impact on emissions occurs over the remaining life of the equipment
GHG impact lifetime ghg reductions ghg reduction 2010	 3.6 Mt CO_2e direct and indirect 0.36 Mt CO_2e direct and indirect	results derived using ISTUM; assumes best practice approaches implemented in 2000 and continued thereafter; marginal fuel for electricity in BC and Quebec is hydro to 2012
Incremental cost (1997$) capital O&M and fuel	 $ 0.0 - $ 32.7 million / yr	O&M and fuel savings is an annual average: actual savings vary over time depending on the time-path of the investment
Net economic cost lifetime NPV (1997$) lifetime 1997$ /tonne	 - $ 233.4 million - $ 64.1 / t CO_2e	using 10% discount rate
Net financial cost lifetime NPV (1997$)	 - $ 111.3 million	using a pre-tax 40% discount rate

Note: a negative cost indicates a net savings. For net financial cost, a positive value represents the amount that would be required to make the action financially feasible from the industry perspective. A project may be financially feasible but not go ahead because considerations other than financial return also influence investment behaviour (eg. capital availability, risk).

The analysis shown in Tables 3.4.8 and 3.4.9 is based on the assumption that reductions in the purchase of electricity in BC and Quebec result in no indirect emission reductions until 2013 because the marginal source of electricity is hydropower through to 2012. If the marginal fuel for utility electricity production in these two provinces is assumed instead to be natural gas, then there is an additional indirect emission reduction of 0.28 Mt CO_2e in BC and 0.32 Mt CO_2e in Quebec. The corresponding cost effectiveness is -$19.4 / t CO_2e for BC and -$18.7 / t CO_2e for Quebec.

Table 3.4.9
Regional Implications of Improved Maintenance and Use of Pulp and Paper Industry Auxiliary Technologies

Region	% Share in Industry Production	GHG Reduction in 2010 Mt CO_2e	Net Economic Costs (10% discount rate) 1997$ mill	Cost Effectiveness 1997$ / Mt CO_2e	Net Financial Costs (40% discount rate) 1997$ mill
Atlantic	12	0.14	-89.8	-65.6	-42.7
Quebec	35	-	-	-	-
Ontario	21	0.16	-96	-59.7	-45.7
Alberta	7	0.07	-47.5	-72	-22.9
BC	25	-	-	-	-
Total	100	0.37	-233.4	-64.1	-111.3

Note: Manitoba/Saskatchewan not included in the analysis because of the small size of their industries. No ghg impacts are shown for BC and Quebec because of the assumption that the marginal fuel for electricity production in these provinces is hydro, which has no emissions. Negative values represent net savings.

3.4.4 Action: Improved Maintenance and Use of Pulp and Paper Mill Steam-Producing Equipment

> ***ACTION:*** ***Adjust maintenance and use of pulp and paper mill steam-producing equipment to achieve best-practice maintenance and operation in all mills***

This action is based on analysis using ISTUM. In the business-as-usual world we assume that mills do not change their levels of maintenance or the way in which they use their steam-producing equipment, including boilers and cogeneration systems. This action then assumes that all mills optimize use of their steam-producing equipment by implementing best-practice approaches to maintenance and use of the equipment in 2000. We assume that optimization improves efficiency by 10% and that operating and maintenance costs associated with using boilers and cogeneration systems will increase by 10% to reflect the increased effort needed to achieve the more efficient use. These increased costs are more than offset by reductions in fuel purchases.

Table 3.4.10
Action Costs and GHG Impacts of Improved Maintenance and Use of Pulp and Paper Steam-Producing Equipment

	Estimate	Assumptions
Lifetime	variable	depends on the age of the technology stock when improved maintenance is implemented - the impact on emissions occurs over the remaining life of the equipment
GHG impact		
lifetime ghg reduction	8.5 Mt CO_2e direct and indirect	results derived using ISTUM; assumes that best practice approaches are implemented in 2000 and continued there after
ghg reduction 2010	0.85 Mt CO_2e direct and indirect	
Incremental cost (1997$)		
capital	$ 0.0	O&M and fuel savings is an annual average: actual savings vary over time depending on the time-path of the investment
O&M and fuel	- $ 73.0 million	
Net economic cost		
lifetime NPV (1997$)	- $ 521.5 million	using 10% discount rate
lifetime 1997$ /tonne	- $ 61.3 / t CO_2e	
Net financial cost		
lifetime NPV (1997$)	- $ 249.1 million	using a pre-tax 40% discount rate

Note: a negative cost indicates a net savings. For net financial cost, a positive value represents the amount that would be required to make the action financially feasible from the industry perspective. A project may be financially feasible but not go ahead because considerations other than financial return also influence investment behaviour (eg. capital availability, risk).

Steam-producing technologies account for about 20-25% of the end-use energy consumption of pulp and paper mills. Improvements in the energy efficiency of the equipment can therefore result in a 2-3% reduction in the industry's energy requirements. The impact on ghg emissions depends on the mix of fuels used to produce steam in each region. Overall, the action reduces emissions while reducing net costs (ie. it provides a net saving).

Table 3.4.11
Regional Implications of Improved Maintenance and Use of Pulp and Paper Steam-Producing Equipment

Region	% Share in Industry Production	GHG Reduction in 2010 Mt CO_2e	Net Economic Cost (10% discount rate) 1997$ mill	Cost Effectiveness 1997$ / Mt CO_2e	Net Financial Cost (40% discount rate) 1997$ mill
Atlantic	12	0.17	-40.3	-23.8	-19.3
Quebec	35	0.37	-264.3	-71.1	-126.2
Ontario	21	0.12	-138.4	-112.5	-65.9
Alberta	7	0.03	-16.5	-67.4	-8
BC	25	0.16	-62	-38.2	-29.7
Total	100	0.85	-521.5	-61.3	-249.1

Note: Manitoba/Saskatchewan not included in the analysis because of the small size of their industries. Negative values represent net savings.

Regional impacts depends on the size of the industry in each region and the types and costs of fuels used by the existing stock of steam-producing technologies. Because Quebec and Atlantic mills typically are more reliant on higher carbon fuels (oil) than are mills in other regions, the greatest ghg reductions occur in these two regions.

3.4.5 Action: High Energy-Efficiency Auxiliary Technologies in Pulp and Paper Mills

> ***ACTION:*** ***All auxiliary technologies purchased in 2000-2010 in pulp and paper mills are at least as efficient as the most efficient technologies currently available.***

This action is based on analysis using ISTUM. The five generic auxiliary technologies are pumps, fans, compressors, conveyors and motors. We assume that in the business-as-usual world purchases of these technologies generally will be based on the life-cycle cost of purchasing and using them, though other considerations will also influence the choice so that the least cost technology will not always be chosen.

Table 3.4.12
Action Costs and GHG Impacts of Adoption of High Efficiency Auxiliary Technologies in Pulp and Paper Mills

	Estimate	Assumptions
Lifetime	5 -30 years	life of motors is 5-25 years depending on size/type; life of fans is 30 years; life of other technologies is 10 years
GHG impact		
lifetime ghg reduction	11.0 Mt CO_2e direct and indirect	results derived using ISTUM; the marginal fuel for electricity in BC and Quebec is hydro after 2012
ghg reduction 2010	0.65 Mt CO_2e direct and indirect	
Incremental cost (1997$)		
capital	$ 48.1 million	O&M and fuel savings is an annual average: actual savings vary over time depending on the time-path of the investment
O&M and fuel	- $ 111.5 million / yr	
Net economic cost		
lifetime NPV (1997$)	- $ 996.1 million	using 10% discount rate
lifetime 1997$ /tonne	- $ 90.8 / t CO_2e	
Net financial cost		
lifetime NPV (1997$)	- $ 419.4 million	using a pre-tax 40% discount rate

Note: a negative cost indicates a net savings. For net financial cost, a positive value represents the amount that would be required to make the action financially feasible from the industry perspective. A project may be financially feasible but not go ahead because considerations other than financial return also influence investment behaviour (eg. capital availability, risk).

For this action, mills purchase only the most energy efficient auxiliary technologies after 2000. Purchases are done at the end of the life of the equipment so that this action depends on the current age profile of the auxiliary equipment stock, and changing the age profile assumption could have a significant impact on the results. Purchases are also made to allow mills to satisfy demand growth. The penetration of the high efficiency technologies rises over time and is a function of the current age profile of the technology stock and the rate of growth in demand.

Table 3.4.13
Regional Implications of Adoption of High Efficiency Auxiliary Technologies in Pulp and Paper Mills

Region	% Share in Industry Production	GHG Reduction in 2010 Mt CO_2e	Net Economic Cost (10% discount rate) 1997$ mill	Cost Effectiveness 1997$ / Mt CO_2e	Net Financial Cost (40% discount rate) 1997$ mill
Atlantic	12	0.22	-109.5	-41.9	-42.2
Quebec	35	0	-296.1	-570.5	-125.4
Ontario	21	0.31	-124	-29.6	-51
Alberta	7	0.12	-89.9	-55.9	-38.6
BC	25	0	-376.5	-101	-162.1
Total	100	0.65	-996.1	-90.8	-419.4

Note: Manitoba/Saskatchewan not included in the analysis because of the small size of their industries. No ghg impacts are shown for BC and Quebec in 2010 because of the assumption that the marginal fuel for electricity production in these provinces prior to 2013 is hydro, which has no emissions. Negative values represent net savings.

The action results in emission reductions with a net reduction in costs (ie. a net savings). About 75% of the emission reduction in 2010 results from adoption of high efficiency pumps (not including pump motors), with most of the remainder coming from adoption of high efficiency fans. This reflects the relative importance and energy intensity of these systems in pulp and paper mills. However, the cost effectiveness of adopting high efficiency equipment in each of the five auxiliary technology classes is very similar.

Increased adoption of high efficiency auxiliary equipment reduces electricity consumption - the ghg emission reductions are almost entirely due to decreased purchases of electricity. Thus the differences in costs across regions reflect differences in electricity costs. Ontario is assumed to have lower electricity costs in the future than Atlantic or Alberta and therefore mills in the province obtain less of a net cost saving.

For BC and Quebec we have assumed that the marginal fuel for electricity is hydro through to 2012 - because of this assumption this action has almost no effect on emissions in these provinces as shown in Table 3.4.13. Alternatively, if the marginal fuel for utility electricity production in these two provinces is assumed to be natural gas, then there is an additional sizeable indirect emission reduction of 0.70 Mt CO_2e in BC and 0.56 Mt CO_2e in Quebec.

3.4.6 Action: High Energy-Efficiency Technologies in Lumber and Panelboard Mills

ACTION:	***Adoption of high energy efficiency process and auxiliary technologies in lumber and panelboard mills to achieve a 10% reduction of ghg emissions per year, below the level in 2000***

This action is based on a targeted annual reduction in ghg emissions from lumber and panelboard mills of 10% below the expected 2000 level of 3.3 Mt CO_2e, or 0.33 Mt CO_2e per year. For comparison, lumber and panelboard mills ghg emissions in 1990 were about 2.3 Mt CO_2e. Panelboard mills include mills which produce softwood and hardwood plywood, oriented strand board, particleboard and medium density fibreboard.

We assume that a 10% reduction in emissions can be achieved through adoption of energy-saving technologies. These include more higher efficiency process technologies like more efficient lumber drying kilns, and more efficient dryers and presses in panelboard mills, all of which use thermal energy. The technologies also include higher efficiency auxiliary technologies which use electricity, such as variable speed drives and more efficient motors and compressors. Individually, the adoption of these technologies can result in emission reductions of 0-20% in mills, and the adoption of several together could reduce emissions by as much as 30% at some mills. Given the diversity of the industry we assumed that a 10% reduction in emissions is a feasible target. Because of the very large number of mills involved (978), the very wide range and age of technologies currently used, and the small emissions emitted by any one regional/industry segment, it was not possible to specify precisely what combination of more efficient technologies could be implemented. Instead, we assumed that an unspecified set of energy efficient technologies could be adopted in mills across the country to achieve the target.

Table 3.4.14
Action Costs and GHG Impacts of Adoption of High Efficiency Technologies in Lumber and Panelboard Mills

	Estimate	Assumptions
Lifetime	20 years	
GHG impact		
lifetime ghg reductions	6.6 Mt CO_2e direct and indirect	estimate assumes all high efficiency technologies implemented in 2000, and the impact starts in 2001
ghg reduction 2010	0.33 Mt CO_2e direct and indirect	
Incremental cost (1997$)		
capital	$ 73.4 million	capital averages $50,000 per lumber mill and $300,000 per panelboard mill; uses projected real energy prices for 2000
O&M and fuel	- $ 4.8 million / yr	
Net economic cost		
lifetime NPV (1997$)	$ 29.0 million	using 10% discount rate
lifetime 1997$ /tonne	$ 4.4 / t CO_2e	
Net financial cost		
lifetime NPV (1997$)	$ 56.8 million	using a pre-tax 40% discount rate

Note: a negative cost indicates a net savings. For net financial cost, a positive value represents the amount that would be required to make the action financially feasible from the industry perspective. A project may be financially feasible but not go ahead because considerations other than financial return also influence investment behaviour (eg. capital availability, risk).

The results are based on an assumption that capital investments to achieve a 10% reduction in ghg emission will average $50,000 per sawmill and $300,000 per panelboard mill. These costs are based on an assessment of the types of higher efficiency technologies that could be applied in each type of mill. Of the 0.33 Mt CO_2e reduction in 2010, 0.19 Mt occurs in lumber mills and 0.14 Mt in panelboard mills. The latter are much more energy intensive - they account for 10% of mills but about 40% of emissions.

Table 3.4.15
Regional Implications of Adoption of High Efficiency Technologies in Lumber and Panelboard Mills

Region	Number of Lumber and Panelboard Mills	GHG Reduction in 2010 Mt CO_2e	Net Economic Cost (10% discount rate) 1997$ mill	Cost Effectiveness 1997$ / Mt CO_2e	Net Financial Cost (40% discount rate) 1997$ mill
Atlantic	154	0.05	3.9	4	6.9
Quebec	242	0.02	6.3	18.6	15
Ontario	145	0.05	4.2	4.5	10
Prairies	122	0.12	3.7	1.6	7.1
BC	315	0.1	8.1	4	16.8
Total	978	0.33	29	4.4	56.8

The reductions are concentrated in Western Canada, in part a reflection of the large number of mills but also because of differences in the fuel mix of mills across the country. Mills in BC and the Prairies use a relatively high proportion of natural gas while Ontario and especially Quebec use relatively more biomass as a fuel. Thus mills in Western Canada tend to have higher ghg emissions. Because Quebec lumber mills use a relatively very high proportion of biomass in their fuel mix, emission reductions are relatively low in the province and the cost per unit reduced is much higher.

3.4.7 Further Assessment of Forest Industry Energy Efficiency Actions

Competitiveness, Economic and Social Implications

The Table's analysis indicated that there are significant intra-sectoral and regional differences in potential cost savings from the energy efficiency measures in the pulp and paper industry which could affect regional competitiveness. Overall, competitiveness and employment impacts will be very mill-specific. There may also be differences in the effect of the actions on larger firms as compared to smaller firms. Larger firms typically have greater access to capital and may be better able to use incentives provided by governments. Therefore they may be better able to undertake the energy efficiency actions described here, and might improve their position relative to smaller companies.

Overall, incremental capital expenditures (ie. above what would be spent in a BAU world) due to the six energy reduction actions could amount to a total of roughly 1997$1.2 billion over the 2000-2010 period (not accounting for the interactions among the actions). Most of the capital investment is needed for process thermal integration and the adoption of new process technologies in the pulp and paper industry.

Positive impacts from investment in energy efficiency equipment and processes will provide spin-off benefits in many technology sectors and indirectly filter into other sectors of the Canadian economy. The estimated capital expenditures could generate as much as 1997$3.1 billion in economic activity, assuming a multiplier of 2.5 to account for indirect and induced activity. However, a significant portion of the initial direct investment likely would be accounted for by machinery and equipment imports rather than through domestic purchases.

Other positive economic benefits from energy reductions in the forest industry could include productivity advancements. Investment in new and improved equipment tend to increase productivity, but it is uncertain how the actions will change productivity trends relative to what would have occurred as a result of capital investments in a BAU world.

The energy cost savings of the forest products industry come as a result of reduced purchases from the energy sector. We have not analyzed the extent of these reductions to any great extent, and it should be kept in mind that the actions may not all be implemented. As well, the actions cannot be simply added because, in practice, implementation will result in interactions which create a lower total effect than the sum of the actions. Nevertheless, we can provide some rough indications of the effects on the energy sector. Reductions in fossil fuel purchases will have negative impacts on domestic fossil fuel exploration, production, transmission, and distribution activities. For example, by itself, improved thermal integration in the pulp and paper industry will reduce fossil fuel purchases by about 1997$100 million per year, or about 23 petajoules per year. Reductions resulting from the other actions could amount to roughly another 1997$200 million per year by 2010 or about 45 petajoules per year, if they are all implemented. Reductions in electricity purchases will also occur - these could amount to about 40-50 petajoules per year by 2010.

Environmental and Health Impacts

Reducing the use of energy derived from fossil fuels through improved thermal integration, the adoption of more efficient technologies, and improved maintenance and use of existing machinery and equipment will reduce cumulative or excessive concentrations of air emission pollutants. Reduction of energy from biomass fuels as a result of lower energy demand will have a similar effect. This can improve air quality and benefit human and ecological health.

More specifically, decreased combustion of fuels reduces CO_2, nitrous dioxide (N_2O) and sulfur dioxide (SO_2), along with smaller amounts of methane (CH_4), carbon monoxide (CO), volatile organic compounds (VOC), and fine particulate matter (PM) emissions. Positive health benefits from the reduction of these pollutants can include decreased susceptibility to lung infections, respiratory problems and immune deficiency to colds and bronchitis. Other potential positive benefits from reduced fossil fuel emissions include less damage to buildings and improved visual aesthetics.

Because the reductions in energy are demand side reductions and do not substitute one energy source for another they are not expected to be any offsetting direct negative impacts on air or water pollution.

Extent of Use of Energy-Efficiency Actions/Measures in Other Countries

Energy efficiency actions are being pursued by some of the major competitors of Canada's forestry industry. The US, Sweden and Finland all have identified interest in reducing the levels of energy use in the forest industry, more specifically the pulp and paper industry, to meet their Kyoto commitments while at the same time improving the competitive position of their industry in the global market.

In the US, Agenda 2020, a partnership between the forest industry, universities and government, will play a pivotal role in efforts to reduce energy use. The goal of Agenda 2020 is to advance the global competitiveness of the US forest industry by regaining a technological advantage over its traditional competitors (i.e., Canada and Scandinavian countries) and newer competitors (i.e., Brazil, Chile, Indonesia, and South Africa). Improved energy performance is a fundamental research area in Agenda 2020. Research and development into manufacturing process efficiency and heat recovery actions identified in Agenda 2020 could have a significant impact on the US industry's future competitive position by reducing energy costs. Specific energy efficiency research areas identified by Agenda 2020 are:

- new technologies for recovery of low-level heat;
- new or more effective approaches to water removal prior to drying;
- commercialization of new and improved drying concepts;
- reduced process variability/improved process control;
- improved wood products, pulping and paper manufacturing processes; and,
- effective and efficient lime kiln operation.

Competitive impacts on the Canadian forest industry from the implementation of Agenda 2020 may arise if similar approaches are not adopted. For example, the adoption of a systems approach is seen by the US Department of Energy as a prime opportunity to reduce the industry's energy use. This implies that Canadian mills may not gain an advantage relative to the US if they implement the process thermal integration action described above, but may be at a disadvantage if they do not implement it.

Finland already has a highly efficient low carbon energy mix but the industry is making continued efforts to increase energy efficiency. The basic framework to achieve this is the Energy Conservation Programme that provides funding for projects designed to conserve energy. Currently, it includes financial aid to the pulp and paper industry for energy analyses and audits. The programme also provides expertise and assistance to those undertaking energy saving projects. Finland generally has used economic instruments to influence energy use; high depreciation rates in addition to many other government incentives have served to foster the current efficient energy profile of the industry and the country as a whole. A combination of high taxes on carbon-based fuels and tax incentives for energy-related projects helped to create the energy efficient state of the Finnish pulp and paper industry.

In Sweden, energy efficiency is an important consideration for meeting ghg emission targets due to the wide availability of advanced technologies by Swedish companies. Particular attention has focussed on finding efficiencies in its transportation sector. Measures to reduce emissions from the transportation of forest products include research into new fuel and engine technology, coordination of log exchanges between mills, heavier transport payloads and improved road systems.

The relative success of the forest industry in Canada in reducing energy use and costs will have domestic and international competitiveness implications. Economies of scale and the current state of mill modernization will have a key influence on energy cost reductions. If larger US firms or technically advanced Swedish firms find it less costly and can adopt energy efficiency technology more quickly than Canadian firms, then these competitors could gain an advantage.

In general, the major segments of the industry have similar energy cost structures across Canada, the US and the Scandinavian producers. Thus no country seems to be at a significant disadvantage and each would appear to have a similar opportunity to benefit from improving energy efficiency. However, this may be changing since in recent years energy cost shares have been falling in Sweden and Finland, whereas energy cost shares for North American producers have been slightly increasing or remaining constant. This reflects the greater modernization of mills in Scandinavia and suggests therefore that there may be relatively fewer opportunities to improve energy efficiency in these mills. Thus while Scandinavian competitors may have become better integrated in terms of process heat use they also may find that the marginal cost of reducing energy consumption further could be relatively high. Therefore, Canada may have a small cost advantage relative to Scandinavian mills in reducing steam energy costs.

Further Analytical/Study Needs

- For the most part, the actions were assessed using a top down approach. Thus a useful means of improving estimates of the effects of the actions would be to undertake mill level case studies to determine how applicable the results might be in practice.
- The impact of the thermal process integration action on indirect emissions needs to be better estimated. The action will reduce process steam use in mills and this in turn will result in a reduction in self-generated power in those mills which use steam turbines, unless accompanied by concurrent projects which increase the electricity-to-steam ratio or reduce electricity requirements. The implications of this effect were not assessed.
- The sensitivity of the results to differing energy price assumptions needs to be explored. In particular, the sensitivity to different assumptions for residue prices, especially on a regional basis, could be substantial.
- The competitiveness, employment and environmental implications of the actions have not been studied in detail, and require more in-depth consideration.

Relationship to Other Actions/Measures

One particularly important impact of energy efficiency actions is that they will reduce the need for wood wastes as well as fossil fuels. For example, the thermal process integration action is estimated to reduce wood waste needs by about 1.6 million oven dried tonnes. This sort of significant reduction in wood waste use will help to counteract the problem of declining residue surpluses and complement the fuel-switching actions described in Section 3.5. This is discussed more in Section 3.8.

Implementing energy efficiency actions concurrently with the cogeneration or gasification actions described in Sections 3.5 and Section 3.6 will offset the reductions in self-generated power that some mills will experience when they apply cogeneration or gasification.

3.5 FOREST INDUSTRY ENERGY OPTIONS - FUEL-SWITCHING ACTIONS

These actions result in reductions in ghg emissions through greater use of renewable biomass energy. Burning wood biomass is considered to result in no net CO_2 emissions as the emissions will be balanced by carbon sequestration if the wood biomass is derived from sustainably managed forests. Burning biomass does, however, result in small quantities of CH_4 and N_2O emissions. The actions assessed by the Forest Sector Table are summarized in Table 3.5.1 and include direct and indirect CO_2, CH_4 and N_2O emission reductions. Note that the impacts of these actions are not necessarily additive.

Table 3.5.1
Summary of Forest Industry Fuel-Switching Actions

Action	Net Economic Cost[1] 1997$ million	Cost Effectiveness[1] 1997$ / t CO_2e	GHG Emission Reduction 2010 Mt CO_2e	Estimated Incentive for Realization[2] 1997$ million
10. Modernization of hog fuel boilers - 35 pulp and paper mills	-25	-2.6	0.48	155
11. Increase number of hog fuel boilers - 12 pulp and paper mills	-134	-3.4	1.33	111
12. Optimize recovery boilers - 35 pulp and paper mills	-120	-15.2	0.39	65
13. Increase wood waste cogeneration - 12 pulp and paper mills (mills sell excess electricity)	-547	-11.1	2.45	247
14. Fuel-switching (three technologies) - lumber and panelboard mills	-165	-5.4	1.51	356

Note: Negative costs represent a saving.

1 Cost effectiveness and net economic cost derived using a 10% discount rate. Cost effectiveness is the NPV of an action (using the 10% rate) divided by the emission reductions over the 'life' of the investment (eg. the serviceable life of a new machine).

2 As defined in Section 3.3.3, the incentive to realize an action is based on the net financial cost of the action (NPV using a pre-tax 40% discount rate). An incentive of zero is shown where the action has net savings in each province/region.

As discussed in Section 3.2.2, there currently exists a surplus supply of residues in Canada and although the surplus will decline in a BAU world by 2010 the surplus will still be sizeable. The difficulty in accessing this surplus for the actions shown in Table 3.5.1 is two-fold. First, it is scattered across the country and there are few areas where large local concentrations exist - they are mainly in BC, Alberta and Quebec though the surplus in Quebec is almost entirely bark which is a lower quality fuel than sawdust or wood shavings. This means that fuel-switching actions outside these areas face a severe limitation unless other more expensive wood waste sources (eg. from logging and sort yards, pulp mill biomass wastes etc.) can be accessed. The second difficulty is the fact that mills in areas with large local surplus residue supplies often already derive much or most of their direct energy needs from wood wastes. Thus in these areas the opportunities for fuel-switching are more limited. This issue is discussed further in Section 3.8.

3.5.1 Action: Hog Fuel Boiler Modernization in the Pulp and Paper Industry

> ***ACTION:*** ***Modernization of hog fuel boiler grates and air systems at 35 pulp and paper mills to allow reduced co-firing with fossil fuels***

At present about 72 pulp and paper mills use hog fuel to fire their boilers. Hog-fired boilers generally require some degree of co-firing with fossil fuel for a variety of reasons, and older boilers tend to use a greater proportion of fossil fuel than do more recent boilers. Older boilers which use fixed grates are often limited in the amount of steam that they can generate using wood only. The reasons include a deterioration of hog quality (ie moisture, bark content, boiler grate deterioration etc) which prevents the boiler capacity rating from being attained. Grate ash removal can mean that auxiliary fossil firing must be used for up to a couple of days per week, depending on ash and sand, while the grate is being cleaned or raked.

Recent grate rebuilds to replace fixed grates with vibrating grates, and air system optimization, have resulted in improvements of up to 20% in steaming capacity. The improvement creates a corresponding need for increased use of wood residues and a reduction in the use of fossil fuel, and therefore reduces ghg emissions. This action assumes that 35 older hog fuel boilers will modernized. It also assumes that existing handling systems can handle the increase in residues required, and that air emission controls are sufficient to handle the increase in emissions (especially given the possibility of increased standards for particulate matter emissions). A need for improved handling systems and installation of improved emission controls will add to the costs.

Table 3.5.2
Action Costs and GHG Impacts of Hog Fuel Boiler Modernization

	Estimate	Assumptions
Lifetime	20 years	the modernization is assumed to occur in 2000-2005
GHG Impact		
lifetime ghg reduction	9.6 Mt CO_2 direct and indirect	
ghg reduction 2010	0.48 Mt CO_2 direct and indirect	
Incremental cost (1997$)		
capital	$ 262.5 million	modernization of 35 boilers
O&M	- $ 17.5 million / yr	boiler grate maintenance costs decrease
fuel	- $ 13.2 million / yr	uses forecast energy prices for 2000
Net economic cost		
lifetime NPV (1997$)	- $ 25.1 million	using 10% discount rate
lifetime 1997$ / tonne	- $ 2.6 / t Mt CO_2e	
Net financial cost		
lifetime NPV (1997$)	$ 155.1 million	using a pre-tax 40% discount rate

Note: A negative cost indicates a net savings. For net financial cost, a positive value represents the amount that would be required to make the action financially feasible from the industry perspective. A project may be financially feasible but not go ahead because considerations other than financial return also influence investment behaviour (eg. capital availability, risk). Changes in emissions of CH_4 and N_2O are accounted for only partially.

The assumed distribution of hog fuel boiler grate rebuilds is based on the current distribution of mills with power boilers fired using hog fuels, current wood waste availability and the relative ghg emission reduction cost effectiveness of the action across the regions. As well, Atlantic Canada and Quebec are assumed to have a generally older population of hog fuel boilers which could be modernized. Thus most of the effect of this action occurs in Quebec and the Atlantic provinces. About 60% of the current surplus wood residues in Atlantic Canada will be used, and between 10% and 35% of the current surplus wood residue levels in each of the other region will be used, for a total of 0.88 million oven dried tonnes.

Table 3.5.3
Regional Implications of Hog Fuel Boiler Modernization

Region	Number of Hog-Fired Power Boilers	Hog Fuel Boilers Modernized	Wood Residue Required million ODt/yr	GHG Reduction in 2010 Mt CO_2	Net Economic Cost (10% discount rate) 1997 $ million	Cost Effectiveness 1997$ / Mt CO_2	Net Financial Cost (40% discount rate) 1997 $ million
Atlantic	16	6 boilers	0.15	0.11	-14.7	-6.4	22.7
Quebec	27	12 boilers	0.30	0.15	-34.7	-11.5	43.4
Ontario	26	6 boilers	0.15	0.08	-6.5	-4.3	25.8
Prairies	7	3 boilers	0.08	0.04	6.9	9.1	16.7
BC	26	8 boilers	0.20	0.10	23.9	11.8	46.5
Canada	102	35 boilers	0.88	0.48	-25.1	-2.6	155.1

Note: A negative cost indicates a net savings.

The majority of mills which produce chemical pulp or newsprint already use some portion of wood wastes in their power boilers. These mills account for about one-half of the mills in the pulp and paper industry and this action would mainly involve these mills.

3.5.2 Action: Increased Use of Hog Fuel Boilers in the Pulp and Paper Industry

ACTION: ***Invest in hog-fired boilers to replace fossil-fired units in the pulp and paper industry***

This action is based on analysis using ISTUM. While the previous action concerned modernization of the existing stock of hog-fired boilers, this action would result in an increase in the stock of hog fuel boilers in the pulp and paper industry. At present about 91 pulp and paper mills in Canada do not use hog fuel to fire their power boilers, but instead rely on fossil fuel. In total, about 219 of the 321 boilers in use in the pulp and paper industry use only fossil fuel.

Table 3.5.4
Action Costs and GHG Impacts of Increased Use of Hog Fuel Boilers in the Pulp and Paper Industry

	Estimate	Assumptions
Lifetime	30 years	
GHG impact		results derived using ISTUM; this action requires investment in hog boilers to replace boilers that have reached the end of their useful life of 30 years; the pattern of investment is a function of the current age of the boiler stock
lifetime ghg reduction	39.4 Mt CO_2e direct and indirect	
ghg reduction 2010	1.33 Mt CO_2e direct and indirect	
Incremental cost (1997$)		O&M and fuel savings is an annual average; actual savings vary over time depending on the time-path of the investment
capital	$ 234.4 million	
O&M and fuel	- $ 35.6 million	
Net economic cost		using 10% discount rate
lifetime NPV (1997$)	- $ 134.2 million	
lifetime 1997$ / tonne	- $ 3.4 / t Mt CO_2e	
Net financial cost		
lifetime NPV (1997$)	$ 110.9 million	using a pre-tax 40% discount rate

Note: A negative cost indicates a net savings. For net financial cost, a positive value represents the amount that would be required to make the action financially feasible from the industry perspective. A project may be financially feasible but not go ahead because considerations other than financial return also influence investment behaviour (eg. capital availability, risk).

This action is a concerted effort to increase the use of wood residues as a fuel by about 15% above the BAU level by 2010 through increased installation of hog-fuel boilers. It requires that, as fossil-fired boilers are retired at the end of their serviceable lives, they will be replaced by hog-fired units. Because CO_2 emissions from the combustion of biomass are not counted in Canada's emissions inventory, the direct substitution of wood residue energy for fossil fuel energy will reduce emissions substantially. Net changes in the emissions of CH_4 and N_2O are counted here. This action has virtually no effect on indirect emissions of the pulp and paper industry.

Table 3.5.5
Regional Implications of Increased Use of Hog Fuel Boilers in the Pulp and Paper Industry

Region	Number of Fossil-Fired Boilers	Wood Residue Required mil ODt/yr	GHG Reduction in 2010 Mt CO_2e	Net Economic Cost (10% discount rate) 1997 $ million	Cost Effectiveness 1997$ / Mt CO_2e	Net Financial Cost (40% discount rate) 1997$ million
Atlantic	19	0.43	0.39	-77.4	-6.5	21.2
Quebec	113	0.32	0.34	-87.8	-8.7	5.1
Ontario	51	0.11	0.12	-27.9	-8.2	1.6
Alberta	16	0.20	0.15	13.4	3.0	23.8
BC	20	0.42	0.33	45.4	4.7	59.1
Total	219	1.48	1.33	-134.2	-3.4	110.9

Note: Manitoba and Saskatchewan not included in the analysis because of the small size of their pulp and paper industries. The number of fossil-fired boilers shown for Alberta includes boilers in Manitoba and Saskatchewan.

We assume a new boiler is purchased only when the existing unit has reached the end of its serviceable life. Thus the distribution across regions of the impact of this action is a function of different boiler stock ages in the various regions and the time at which they must be replaced. The distribution is also a function of the residues available in each region. As Quebec and the Atlantic region have relatively older stocks, there exist greater opportunities to switch to hog-fired boilers and cogenerators in those regions in the near term. This action will create a wood residue deficit in the Atlantic region based on the current residue availability described in Section 3.2 - this result is a function of the level of imprecision in the model and suggests that further analysis is required. The action requires less than 25% of current surplus wood residue levels in each of the other regions.

Most mills (about 80%) which use only fossil fuels in their power boilers are integrated or non-integrated operations that do not produce chemical pulp or newsprint, but instead produce other paper and paperboard products and/or mechanical pulp. Thus it is these latter types of mills which will be most affected by this action.

3.5.3 Action: Chemical Pulp Mill Recovery Boiler Optimization

> ***ACTION:*** ***Optimization of recovery boiler air, water and pulping liquor delivery systems at 35 chemical pulp mills***

Mills producing chemical pulp, often combined with the production of mechanical pulps, newsprint or other paper and paperboard products, account for roughly 80% of energy use in the pulp and paper industry. The two main in-house sources of energy in chemical pulp mills are power boilers fired by fossil and wood residue fuels, and recovery boilers fired by spent pulping liquor. Because it is derived from biomass, burning of pulping liquor is considered to have a neutral effect on CO_2 emissions.

There are about 61 recovery boilers in use today at chemical pulp mills in Canada. Those that are ten years or older are considered candidates for improvements in steam production of about 5% through various means of optimizing air (oxygen enrichment), water, and sometimes liquor delivery systems. The increase in energy from liquor (biomass) will reduce the need for auxiliary fossil fuel in the recovery boiler and could reduce the need for steam derived from the use of fossil-fuel boilers. Other benefits include reduced boiler plugging, downtime and maintenance costs. For this action we assumed that modernization of 35 of the recovery boilers is a realistic target.

Table 3.5.6
Action Costs and GHG Impacts of Recovery Boiler Optimization

	Estimate	Assumptions
Lifetime	20 years	all optimization projects are assumed to occur by 2005
GHG impact		
lifetime ghg reductions	7.9 Mt CO_2 direct and indirect	
ghg reduction 2010	0.39 Mt CO_2 direct and indirect	
Incremental cost (1997$)		
capital	$ 175.0 million	applied at 35 mills
O&M	- $ 8.8 million / yr	maintenance costs decrease
fuel	- $ 22.8 million / yr	uses forecast energy prices for 2000
Net economic cost		
lifetime NPV (1997$)	- $ 120.2 million	using 10% discount rate
lifetime 1997$ / tonne	- $ 15.2 / t Mt CO_2	
Net financial cost		
lifetime NPV (1997$)	$ 64.8 million	using a pre-tax 40% discount rate

Note: A negative cost indicates a net savings. For net financial cost, a positive value represents the amount that would be required to make the action financially feasible from the industry perspective. A project may be financially feasible but not go ahead because considerations other than financial return also influence investment behaviour (eg. capital availability, risk).

Table 3.5.7
Regional Implications of Recovery Boiler Optimization

Region	Number of Chemical Pulp Mills	Recovery Boilers Optimized	GHG Reduction in 2010 Mt CO_2	Net Economic Cost (10% discount rate) 1997 $ million	Cost Effectiveness 1997$ / Mt CO_2	Net Financial Cost (40% discount rate) 1997 $ million
Atlantic	7	5 boilers	0.08	-26.3	-16.5	5.8
Quebec	19	10 boilers	0.11	-56.4	-26.9	10.3
Ontario	11	6 boilers	0.06	-24.8	-19.6	9.6
Prairies	7	4 boilers	0.04	-5.3	-6.3	10.6
BC	17	10 boilers	0.11	-7.4	-3.5	28.6
Canada	61	35 boilers	0.39	-120.2	-15.2	64.8

Note: A negative cost indicates a net savings.

This action applies only to mills which produce chemical pulp. The assumed distribution of optimization projects is based on the current distribution of recovery boilers, the share of energy consumption from pulping liquor in each province, and the relative ghg emission reduction cost effectiveness of the action across the regions.

3.5.4 Action: Increase Woodwaste Cogeneration in the Pulp and Paper Industry

> ***ACTION:*** ***Increase the use of biomass cogeneration in the pulp and paper industry through the establishment of 12 wood-waste cogenerating facilities***

In much of Canada, pulp mills have been encouraged to burn cheap and abundant natural gas. In many cases mill boilers are designed to burn exclusively or primarily natural gas or other fossil fuels, leaving little potential for use of wood residues. However, greater use of the surplus that exists in parts of Canada could make an important contribution to meeting Canada's ghg emission reduction target. One way to do this is to build new wood waste cogeneration facilities to supply mills' thermal energy needs while at the same time making the mills electrical energy self-sufficient and reducing their purchases of electricity produced using fossil fuels. The opportunity to generate power from surplus woodwaste through expanding the use of cogeneration in the pulp and paper industry is one of the most efficient ways currently available to make use of the surplus, from the perspective of reducing ghg emissions.

This action is based on an assessment of biomass cogeneration projects already under consideration that would likely be undertaken if various impediments could be overcome. Details of each project were obtained and used in the analysis, and therefore reflect specific site conditions and approaches. In the analysis it is assumed that fuel handling systems and precipitators to handle particulate emissions are sufficient and have been accounted for in the costs.

From the perspective of mills, the ability to sell excess electricity can be a key factor in determining the financial viability of wood waste cogeneration projects. This is made apparent in Table 3.5.8 where the costs are shown in the case where the excess cannot be sold, as well as the case where the excess can be sold. The ability to sell the excess power makes the projects much more viable and, from the perspective of ghg emission reductions, also makes wood waste cogeneration a much more cost effective option. This is because revenue is obtained from the sale of the electricity - we assumed that excess electricity could be sold at 4 cents per kWh. It also results because the electricity replaces utility electricity produced using fossil fuels, resulting in substantial indirect emission reductions. The estimates here are based on the assumption that the marginal source of electricity in Quebec and BC is hydropower. If it were natural gas, the indirect emission reductions resulting from the 5 cogen projects in these provinces would be substantially greater, and the overall cost effectiveness would also be improved. Note that with an electricity sale price of 4 cents per kWh the estimated net financial cost is $211 million - the net financial cost is zero if electricity can be sold at 6 cents per kWh.

One of the greatest impediments to wood waste cogeneration is the capital cost of the installation relative to the costs of electricity produced using combined cycle natural gas systems, especially when financing of large projects not directly related to production of pulp and paper is difficult to obtain. It is this difficulty which has encouraged the growth of the 'energy island' concept in which a third party owns the power production facility, leaving the mill to concentrate on its core business. The security of a long-term supply of wood waste is another serious concern.

Table 3.5.8
Action Costs and GHG Impacts of Increased Use of Wood Waste Cogeneration

	Estimate	Assumptions
Lifetime	20 years	assumes cogeneration facilities are fully operational by 2005
Incremental cost (1997$)		
capital	$ 662.8 million	capital and O&M costs of each project vary according to site-specific conditions, technology choice and project size
O&M	$ 20.6 million / yr	
fuel	- $ 31.8 million / yr	uses forecast energy prices for 2000; see Table 3.2.1
electricity	$ 118.0 million /yr revenue	assumes electricity sold at 4 cents per kWh
Mills Can Sell Electricity		
GHG impact		
lifetime ghg reductions	49.1 Mt CO_2 direct and indirect	estimates based on 12 wood waste cogeneration projects considered to be good candidates for implementation
ghg reduction 2010	2.46 Mt CO_2 direct and indirect	
Net economic cost		
lifetime NPV (1997$)	- $ 547.2 million	using 10% discount rate
lifetime 1997$ / tonne	- $ 11.1 / t Mt CO_2	
Net financial cost		
lifetime NPV (1997$)	$ 211.1 million	using a pre-tax 40% discount rate
Mills Cannot Sell Electricity		
GHG impact		
lifetime ghg reductions	28.2 Mt CO_2 direct and indirect	estimates based on 12 wood waste cogeneration projects considered to be good candidates for implementation
ghg reduction 2010	1.41 Mt CO_2 direct and indirect	
Net economic cost		
lifetime NPV (1997$)	$ 558.2 million	using 10% discount rate
lifetime 1997$ / tonne	$ 19.8 / t Mt CO_2	
Net financial cost		
lifetime NPV (1997$)	$ 623.6 million	using a pre-tax 40% discount rate

Note: a negative cost indicates a net savings. For net financial cost, a positive value represents the amount that would be required to make the action financially feasible from the industry perspective. A project may be financially feasible but not go ahead because considerations other than financial return also influence investment behaviour (eg. capital availability, risk).

The distribution of the cogeneration projects is based on an assessment of biomass cogeneration projects that have been proposed but have not proceeded to date due to barriers of various kinds generally related to costs. No biomass cogeneration projects for Atlantic Canada were included in the estimates but one such project in Newfoundland was identified as this report was being finalized - the details were not available to consider its inclusion in this action.

Table 3.5.9
Regional Implications of Increased Use of Wood Waste Cogeneration and Sale of Excess Electricity

Region	Number of Cogeneration Projects	Wood Residue Required mill ODt /yr	GHG Reduction in 2010 Mt CO_2	Net Economic Cost (10% discount rate) 1997 $ million	Cost Effectiveness 1997$ / Mt CO_2	Net Financial Cost (40% discount rate) 1997 $ million
Atlantic	-	-	-	-	-	-
Quebec	1	0.18	0.12	-112.5	-46.7	-35.7
Ontario	3	0.44	0.60	-137.9	-11.4	58.2
Prairies	4	0.88	1.34	-235.4	-8.7	76.2
BC	4	0.55	0.38	-61.5	-8.2	112.4
Canada	12	2.05	2.46	-547.2	-11.1	211.1

Note: a negative cost indicates a net savings.

While the Table did not assess any biomass cogeneration projects in Atlantic Canada, residue availability is greatest in BC and Alberta and it is in these provinces that most of the activity would occur. The implementation of the cogeneration projects would use almost all available the residues currently available in Ontario and Prairies but only a small portion of the residues available in Quebec and BC. Differences in the ghg impacts across provinces reflect primarily the assumptions about the marginal source of electricity in the provinces - the reductions in Quebec and BC are relatively low because of the assumption that the marginal source is hydropower.

3.5.5 Action: Fuel-Switching in Lumber and Panelboard Mills

ACTION:	***Adoption of fuel-switching technologies in lumber and panelboard mills to reduce ghg emissions by almost 40% in 2010***

Analysis of this action started with an assessment of emissions and fuel-switching opportunities by region, mill type (lumber, various types of panels) and mill size. Only those region/industry segments with direct and indirect ghg emissions above 0.01 Mt CO_2e were considered, and only larger mills were assumed to adopt fuel-switching technologies. For each segment we considered three types of fuel-switching technologies: 1) biomass substitution using biomass-fired furnaces; 2) biomass-fired cogeneration of electricity; and 3) natural gas fired cogeneration of electricity. These technologies are used to achieve a target reduction in direct and indirect ghg emissions in 2010 of almost 40% below the expected BAU level of 4.1 Mt CO_2e. Panelboard mills include mills which produce softwood and hardwood plywood, oriented strand board, particleboard and medium density fibreboard.

In most region/industry segments, significant emission reductions result from increased use of biomass-fired furnaces and thermal systems, which can achieve almost 100% reduction in direct ghg emissions when they replace fossil-fired units. A critical assumption was that different sizes of furnaces and thermal systems could be adapted to the various types of fossil fuel use in mills. In some segments, such as Alberta lumber mills and panel mills in Alberta, Saskatchewan and Ontario, indirect emissions are a relatively high portion of total emissions so that cogeneration technologies were also considered for reducing emissions. Biomass-fired cogeneration was assumed to be used in some large oriented strandboard mills because it can reduce indirect emissions from purchased electricity based on fossil fuels by about 95%. This is an expensive technology but it has been proven over the size range required for these mills, and is the best means of reducing indirect emissions at electricity-intensive panel mills. Natural gas cogeneration was assumed to be used at some mills in the Prairies. Natural gas cogeneration reduces indirect emissions when it replaces electricity produced by a utility using single cycle gas power plants, which are less efficient, or when it replaces electricity produced using higher carbon content fuels.

Table 3.5.10
Action Costs and GHG Impacts of Adoption of Fuel-Switching Technologies in Lumber and Panelboard Mills

	Estimate	Assumptions
Lifetime	20 years	
GHG impact		
lifetime ghg reductions	30.2 Mt CO_2e direct and indirect	estimate assumes all fuel-switching technologies implemented in 2000, with the impact starting in 2001
ghg reduction 2010	1.51 Mt CO_2e direct and indirect	
Incremental cost (1997$)		
capital	$ 666.5 million	
O&M and fuel	- $ 88.8 million / yr	uses projected fuel prices for 2000: see Table 3.2.1
Net economic cost		
lifetime NPV (1997$)	- $ 164.8 million	using 10% discount rate
lifetime 1997$ /tonne	- $ 5.4 / t CO_2e	
Net financial cost		
lifetime NPV (1997$)	$ 356.2 million	using a pre-tax 40% discount rate

Note: a negative cost indicates a net savings. For net financial cost, a positive value represents the amount that would be required to make the action financially feasible from the industry perspective. A project may be financially feasible but not go ahead because considerations other than financial return also influence investment behaviour (eg capital availability, risk).

Table 3.5.11
Regional Implications of Adoption of Fuel-Switching Technologies in Lumber and Panelboard Mills

Region	Number of Lumber and Panelboard Mills	Additional Wood Residue Requirements million ODt	GHG Reduction in 2010 Mt CO_2e	Net Economic Costs (10% discount rate) 1997$ mill	Cost Effectiveness 1997$ / Mt CO_2e	Net Financial Costs (40% discount rate) 1997$ mill
Atlantic	154	0.21	0.21	-63.6	-15.0	18.0
Quebec	242	0.05	0.04	-4.9	-5.5	11.7
Ontario	145	0.39	0.21	-31.1	-7.3	134.4
Prairies	122	0.21	0.54	-76.4	-7.1	106.0
BC	315	0.66	0.51	11.1	1.1	86.1
Total	978	1.52	1.51	-164.8	-5.4	356.2

Note: a negative cost indicates a net savings.

There are far fewer panelboard mills (98) than lumber mills (880) - the former are much more energy intensive though they currently obtain a greater share of their energy needs from biomass (70%) than do lumber mills (50%). The net result is that adoption of the fuel-switching technologies reduces 2010 direct and indirect emissions of lumber mills by 46% or 0.93 Mt CO_2e, and reduces 2010 emissions of panelboard mills by 28% or 0.58 Mt CO_2e.

The reductions are concentrated in BC lumber mills, and Prairie (mainly Alberta) lumber and panelboard mills, reflecting variations in fuel mix, industry size and the energy intensity of specific industry segments. The large size of the BC lumber industry (45% of Canadian production) largely accounts for its contribution to the reduction. Mills in the Prairies tend to have more emission intensive production and therefore have more scope for reductions. Differences in cost effectiveness across regions result from differences in fossil fuel and electricity prices.

A key uncertainty in achieving the emission reduction target of this action is the availability of sufficient residues. The wood residue requirements for this action exceed the projected 2010 residue surplus in a BAU world in each region except Quebec and BC. However, other actions will reduce the requirement for residues - see Section 3.8 for a discussion of the combined impact of all energy actions on residues.

3.5.6 Further Assessment of Forest Industry Fuel-Switching Actions

Competitiveness, Economic and Social Implications

Aside from the direct energy cost savings, some of the actions can have other positive indirect impacts which affect competitiveness. For example, recovery boiler optimization is often accompanied by increases in mill throughput, which improves competitiveness.

Employment benefits from construction activities likely will have a significant impact on local area economies near mills. As well, mill employment should increase with most of the actions due to changes in maintenance and feedstock handling requirements. In general, increased use of wood residues requires additional labour intensive handling of residues which likely will provide positive employment impacts at some mills and local spin-off transportation benefits and as well as emissions. OECD research suggests that, depending on the type of biomass source, forest biomass energy provides 25 to 113 person years of employment per petajoule. Using fibre from energy plantations represents the high end of this range, while using residues from pulp and paper, sawmills and log sort yards represents the bottom portion of the range. For comparison, coal energy is estimated to generate approximately 8 person-years per petajoule. Aggregating the sawmill and pulp and paper industry, the forest product industry's employment potential from increased use of biomass energy is estimated to be 42 person-years per petajoule, significantly higher than for fossil fuels. However, caution must be used in determining the overall net impact on employment. If wood residues come from existing mill sources, employment from using biomass likely will displace current employment in wood residue disposal activities.
In terms of economic impacts outside the forest industry, expansion or additions to the forest industry's biomass energy use will result in additional economic and social benefits from equipment purchases and plant construction. Incremental capital expenditures (ie. above what would be spent in a BAU world) due to the five fuel-switching actions we assessed could amount to a total of about 1997$2 billion in the 2000-2010 period (not accounting for the interactions among the actions). Assuming a multiplier of 2.5 this could create as much as 1997$5 billion in economic activity spread out over the investment period. Much of this economic activity may be exported, depending on the location of major equipment suppliers.

There will be negative economic impacts from the fuel-switching actions, as a result of impacts on fossil fuel industry exploration, production, transmission, and distribution activities. We have not analyzed the extent of these reductions to any great extent, and it should be kept in mind that the actions may not all be implemented. As well, the actions cannot be simply added because, in practice, implementation will result in interactions which create a lower total effect than the sum of the actions. Nevertheless, we can provide some rough indication of the effects on the energy sector. Assessed individually, the increased use of residues for energy is equivalent to replacing about 80 petajoules of fossil fuel in 2010 compared to the BAU world. Accounting for the overlap and interaction among the actions suggests that the actual reductions in fossil fuel purchases would be much less.

While the capital costs of fuel-switching actions can be high, information from the *Pulp and Paper Review* of Resource Information Systems Inc. shows that biomass is a relatively low cost source of energy in Canada in newsprint mills, as shown in Table 3.5.12. As well, the cost of biomass to Canadian newsprint mills is much lower than the costs faced by their major competitors in the US, Finland and Sweden. Canada's newsprint mills also pay less for natural gas, on average, than their US competitors. Compared to the US, switching to hog fuel from natural gas or fuel oil will in some cases reduce energy costs ($ per gigajoule) more in Canada than in the US depending on the location of mills. For example, switching to hog fuel from oil in Eastern Canada will reduce energy costs more than when this occurs in the US. In contrast, US mills will gain more of a cost reduction than Eastern Canadian mills when natural gas is replaced by hog fuel. Of particular note with respect to the United States is that switching from coal (which is used extensively in the US pulp and paper industry) to hog fuel provides only small cost savings. Similarly, switching from oil to hog fuel provides a relatively small cost reduction in Finland compared to Canada, and actually will increase costs in Sweden. Overall, based on average fuel input costs, Canada has a slight competitive fuel-switching advantage over the US, Finland and Sweden in newsprint, and this likely holds for other segments of the pulp and paper industry as well.

It is important to note that this comparison of energy prices assumes that each country adopts similar fuel-switching technologies and faces similar capital equipment costs. These may not be unrealistic assumptions since many forestry nations are considering similar fuel-switching activities and the market for cogeneration equipment is generally a competitive global market. Any differences among countries are more likely to result from differences in capital cost allowances, renewable energy tax incentives and green power initiatives. Therefore, from a global competitiveness perspective it is important that the Canadian forest industry face a similar incentive structure to that found in other forestry nations, or that the net impacts are similar.

Table 3.5.12
Newsprint Regional Energy Cost Comparisons, 1997

Region	Natural Gas	Fuel Oil	Purchased Hog Fuel	Coal	Other Sources of Heat	Purchased Power	Self-Generated Power	Purchased Hog Fuel
	(C$ per GJ)					(C$ per KWh)		(C$ per ODt)
Eastern Canada	--	4.08	1.26	--	0.95	3.7	1.2	22.13
Western Canada	--	4.08	0.55	--	1.12	3.8	1	9.77
Canada	3.24	4.08	--	2.65	--	--	--	
US South	6.25	5.17	2.90	--	4.64	4.6	1.3	50.97
US Northwest	5.02	5.21	2.6	--	3.26	4.7	3.4	45.78
US	--	--	--	3.01	--	--	--	
Finland	--	4.67	3.84	--	6.49	3.8	3.8	67.6
Sweden	--	1.77	1.99	--	3.3	2.9	2.7	35.1

Environmental and Health Impacts

Decreased combustion of coal, natural gas and oil will reduce CO_2, nitrogen dioxide (NO_x) and sulfur dioxide (SO_2), along with smaller amounts of CH_4, carbon monoxide (CO), volatile organic compounds (VOC), and fine particulate matter (PM) emissions. Positive health benefits from these reductions can include decreased incidence of lung infections, respiratory problems and immune deficiency to colds and bronchitis. Other positive benefits include less damage to buildings, improved visual aesthetics and reduced plant and habitat damage.

Potential adverse environmental effects from increased combustion of biomass include a net increase in the levels of PM, VOC and CH_4. PM emissions can lead to reductions in visibility. There are also concerns that PM emissions may induce human respiratory problems but some Table members believe that the uncertainty and debate about the linkages between PM emissions and human health effects mean that no conclusions can be drawn yet. Expansion or addition of new biomass energy projects will reduce the use of wood waste incinerators that currently dispose of sawmill residues without energy recovery or, in some cases, modern emission control devices. Many of these wood residue incinerators are located in smoke sensitive areas (e.g., low lying valleys) where emissions can be trapped for some time, increasing concerns about negative human health impacts and environmental damages. Increased use of wood residues in energy production facilities with proper emission control devices will significantly reduce damages from PM, VOC and CH_4 emissions in these areas of concern, with the added benefit of generating renewable energy that displaces fossil fuels.

Table 3.5.13 summarizes the net air emission impacts associated with selected types of fuel switching, based on emissions factors used by the US Environmental Protection Agency (EPA AP-42 emission factors). Switching to biomass from residual fuel oil sources will significantly reduce emissions of SO_2, NO_x and PM (on a kg per GJ basis). However, in other cases switching to biomass fuel sources causes slight increases of these contaminants. People who live in smoke sensitive areas or in close proximately to facilities with biomass power boilers may experience higher concentrations of PM if proper pollution controls are not in place.

Other potential adverse effects from increased biomass energy generation may include an increase in energy consumption as a result of higher environmental protection (capture of fine PM emissions) technologies. Biological treatment plants and electrostatic precipitators that reduce atmospheric emissions have large energy requirements.

Overall, reducing the level of high carbon fossil fuels used in the forest industry will not only result in reduced CO_2 emissions, but also can have additional benefits from the reduction of other air pollutants that negatively impact the environment and human health (NO_x, CH_4, CO, and SO_2). Proper pollution control devices and improved combustion performance of boilers are necessary to mitigate the risk of health and environmental damage from a possible increase in PM, VOC and CH_4 emissions from biomass power boilers. Increased emission controls could add to the cost of the actions, though we did not take this into account in the actions analysis.

Table 3.5.13
Changes in Air Quality from Fuel Switching Actions

Action	Changes in Air Emissions (kg per GJ x 10-3)				
	CO_2	CH_4	SO_x	NO_x	PM
Fuel Switching					
To hog fuel from natural gas	-50,000	3.76	4.25	-10	4.4
To hog fuel from residual oil	-74,000	1.93	-445	-90	-32.4
To natural gas from residual oil	-24,000	-1.90	-450	-80	-36.2
Optimization/Fuel Switching					
To black liquor from natural gas	-50,000	--	169	--	457
To black liquor from residual oil	-74,000	--	-280	--	100

Extent of Use of Fuel Switching Actions/Measures in Other Countries

The extent of any forest industry fuel-switching actions being pursued by other countries is not known, but some insight can be gained by comparing current biomass use for energy. The Canadian pulp and paper industry currently obtains close to 55% of its energy needs from biomass. Based on the current share of wood wastes and spent pulping liquor in the total energy needs of the pulp and paper industry in the United States and the major Scandinavian producers, the potential for fuel-switching to reduce ghg emissions may be higher in the US and Finland since these two countries currently derive 45-50% of their energy from biomass. For example, recovery boiler optimization is expected to be of significant interest in the United States. Conversely, Sweden likely has fewer opportunities given that close to 60% of its pulp and paper energy needs are already supplied by biofuels. The potential in the US, Finland and other countries will be determined in part by the availability of competitively priced wood residues, as it is in Canada. The United States industry, which relies relatively heavily on coal, also could reap significant ghg emission-reducing benefits by switching to natural gas.

The use of wood waste cogeneration has been supported in the United States through a variety of policies including green pricing policies which include biomass in several states. Some customers are willing to pay more for green power and this helps to offset the higher costs of producing biomass generated energy. The current regulations and market structure of the US electrical industry (i.e., deregulation, green power pricing, renewable energy subsidies, renewable set-asides, etc.), gives the US forest industry more flexibility to promote and take advantage of fuel-switching opportunities than is the case in Canada. Also of relevance in the US is the Public Utility Regulatory Policies Act (PURPA) which explicitly encourages cogeneration by independent power producers, including pulp and paper mills. In the early 1980s this Act was a key driver in expansion of wood waste cogeneration in the US industry. The US Administration is now considering a Renewable Portfolio Standard which, if implemented, would add an impetus to cogeneration in the pulp and paper industry. The proposed standard would require electricity sellers to purchase 5.5% of their electricity supply from renewable sources by 2010.

In terms of forward-looking objectives, one goal of the US pulp and paper Agenda 2020 is for the forest industry to substantially decrease its reliance on fossil fuel and purchased power. Some of the fuel conversion and electricity possibilities that have received considerable attention are biomass and black liquor gasification combined cycle, combustion turbines for dirtier and lower energy content fuels, improved energy conversion technologies, and further utilization of unused biomass.

European competitors, such as Finland and Sweden, have significantly reduced their industrial fossil fuel dependency since the oil crisis in the early 1970s. Considerable efforts by the Finnish government to increase the use of biomass energy have been quite successful. Similar efforts by the Swedish government have also led to the increased use of biomass energy though the country still relies on nuclear power for a significant portion of total power generation. Sweden has committed to shut down their nuclear reactors by 2010, which suggests that in order to meet Kyoto commitments nuclear power must be displaced by renewable energy such as hydro and biofuels. The Swedish Forest Industries Association (SFIA) is not in favour of the displacement of nuclear power by expanding the utilization of biofuels. The SFIA fears that displacing electricity from nuclear power with other sources would result in increased energy prices, which would harm the competitiveness of the Swedish forest industry. Other concerns are over the large amounts of alternative fuel capacity that will have to be installed to offset the small reduction in nuclear capacity.

Taxes and subsidy schemes have been traditionally used by these governments to accelerate biofuel use. In particular a tax on carbon-based fuels has been credited with the movement to switch from fossil fuels to biofuels in Swedish district heating, and combined heat and power applications. Increasing the current use of residues in the Swedish and Finnish forest industry to generate electricity is recognized as an important action to meet the needs of economic growth and Kyoto commitments. The forest industry in Finland and Sweden recommended that the government consider the following when setting fuel switching energy policies:

- existing high energy efficiency must be considered when setting targets for the climate strategy;
- energy taxes should be equivalent to competing countries;
- all alternatives for electricity production should remain available in the future;
- competition in the energy markets must be secured; and,
- use of renewable energy sources should be promoted.

Since Finland and Sweden have already made significant efforts to displace fossil fuel energy with renewable energy, they will likely experience higher costs if further steps are taken. Both countries favour the use of economic instruments to influence fuel-switching behaviour which could provide the forest industry with a flexible and cost-effective policy environment. Government administration costs have been low and industry has been receptive to a policy that allows flexibility to achieve the required standards. In addition, there have been many tax subsidies offered to industry to undertake research and development, and to invest in renewable energy technologies.

A recent initiative by the Swedish National Energy Administration provides $182 million to undertake investments in renewable power sources which include biofuel power and heating plants, wind power and small-scale water power. Although such policies will assist the forest industry in its competitive position, other policies are expected to have the reverse effect. For example, a recent proposal to the Swedish government to impose a tax on landfills to encourage recycling of organic waste will likely have a negative impact on the pulp and paper industry. The Confederation of European Paper Industries (CEPI) suggest that the implementation of such a policy will create an economic disadvantage to their 1,300 member paper mills. Estimates by CEPI suggest that an average mill with an annual capacity of 250,000 tonnes will likely face additional costs of $6.1 million per year.

It is very difficult to determine the overall effects of the fuel-switching options on the Canadian forest industry's competitive position since it is unknown what specific policies will be implemented by competing forestry nations. However, it seems likely that most forestry countries will be adopting similar approaches in meeting ghg emission reductions, fuel-switching and energy efficiency actions. Nations that will obtain a competitive advantage will be those that can adopt fuel-switching technologies without increasing energy costs. Compared to other forestry nations, Canada has an advantage due to its availability of low cost energy inputs such as biomass and natural gas.

Further Analytical/Study Needs

- Improvements in biomass fuel quality can have both fuel-switching and energy efficiency impacts but were not assessed. For example, reducing the moisture content of hog fuel will reduce the amount of fossil fuel co-firing required in hog-fuel boilers. As another example, some mills use a substantial quantity of effluent and recycled paper biomass sludges along with wood residues in their power boilers. Replacing the sludge with greater use of residues reduces fossil-fuel co-firing and improves boiler efficiency.
- A key area of uncertainty is the future supply of wood residues and the constraints this may place on future fuel-switching possibilities. Related to this is the potential to use other biomass sources such as agricultural and municipal wastes.
- Both the net environmental effect of increased fuel-switching and the cost of enhanced emissions control at mills which increase their use of biomass fuel need to be explored further.
- The sensitivity of the results to differing energy price assumptions needs to be explored. In particular, the sensitivity to different assumptions for residue prices, especially on a regional basis, could be significant and could affect policy recommendations.

Relationship to Other Actions/Measures

The various fuel-switching actions assessed by the Table need to be considered in combination to assess how the assumed wood residue use relates to projected wood residue availability. It is likely that not all the actions will be possible, at least at the level described in the actions analysis, given the Table's assessment of future business-as-usual wood residue availability. At the same time, the thermal process integration and other energy efficiency actions described in Section 3.4, if undertaken, will release a substantial quantity of residues. This is discussed more in Section 3.8.

Several of the fuel-switching actions do not actually increase use of wood residues but instead make better use of the biomass fed to recovery boilers (recovery boiler optimization and lignin precipitation). These actions also complement process thermal integration and other steam conservation projects as kraft mills often produce excess steam. They also complement black liquor integrated gasification combined cycle cogeneration action, a longer term more speculative action described in Section 3.6. However, lignin precipitation and the use of the lignin to fuel lime kilns would not be undertaken at the same time as wood biomass gasification for lime kilns, an action also described in Section 3.6.

3.6 FOREST INDUSTRY ENERGY CONSUMPTION OPTIONS - EMERGING TECHNOLOGIES

These actions are based on the application of technologies or approaches which are not now commercially available or applied in Canada, but which the Forest Sector Table believes have a good chance of being applied by 2010 if there are appropriately directed efforts such as policies to accelerate research, development, commercialization and dissemination of specific technologies. These efforts could also include framework policies to encourage a drive for modernization. The actions assessed by the Forest Sector Table are summarized in Table 3.6.1. Note that the impacts of these actions are not necessarily additive.

Table 3.6.1
Summary of Forest Industry New and Emerging Technology Actions

Action	Net Economic Cost[1] 1997$ million	Cost Effectiveness[1] 1997$ / t CO_2	GHG Emission Reduction 2010 Mt CO_2e	Estimated Incentive for Realization[2] 1997$ million
1 Reductions in water use through progressive system closure - 10 pulp and paper mills	32	5.3	0.31	200
2 Black liquor integrated gasification and combined cycle cogen - 3 pulp and paper mills (mills sell excess electricity)	-622	-28.5	1.09	0
3 Biomass gasification to feed lime kilns - 10 pulp and paper mills	291	47.1	0.31	287
4 Adoption of high intensity driers - paper mills	-516	-85.9	0.21	0
5 Lignin precipitation / improve recovery boiler operation - 45 pulp and paper mills	88	20.2	0.22	146

Note: Negative costs represent a saving.

1 Cost effectiveness and net economic cost derived using a 10% discount rate. Cost effectiveness is the NPV of an action (using the 10% rate) divided by the emission reductions over the 'life' of the investment (eg. the serviceable life of a new machine).

2 As defined in Section 3.3.3, the incentive to realize an action is based on the net financial cost of the action (NPV using a pre-tax 40% discount rate). An incentive of zero is shown where the action has net savings in each province/region.

Of particular interest to the forest industry is the potential of gasification technologies. We examined gasification of pulp and paper mill black liquor and biomass gasification to feed chemical pulp mill lime kilns. One potentially important application we did not examine is biomass gasification for use in the wood products sector, including for drying kilns at lumber mills.

In Table 3.6.1 we show the estimated direct incentive need to realize each action. However, we emphasize that achieving these actions is much more than a question of obtaining a sufficient return. To a large extent, the actions are limited by factors such as insufficient capital, a lack of information and the riskiness of making large investments in new and unproven technologies. Thus efforts to address these other limitations will also be necessary if the industry is to undertake the actions.

3.6.1 Action: Pulp and Paper Mill Water Use Reduction

> ***ACTION:*** ***Work toward progressive system closure in 10 pulp and paper mills to recover heat in waste streams, yielding a 60% reduction in water heating requirements at the mills***

Pulp and paper mill processes use large volumes of water, much of which is heated using fossil fuels before addition to the processes, and much of the heat energy is lost through discharge of warm effluent. In working toward system closure, valuable resources contained in waste streams are recovered and reused instead of being discharged to the environment. These resources include water, fibre, chemicals and energy. The process heat loss would be progressively reduced as effluent discharges are reduced.

Table 3.6.2
Action Costs and GHG Impacts of Pulp and Paper Water Use Reduction

	Estimate	Assumptions
Lifetime	20 years	
GHG impact		
lifetime ghg reduction	6.1 Mt CO_2e direct	10 mills achieve a 60% reduction in water usage by 2010
ghg reduction 2010	0.31 Mt CO_2e direct	
Incremental cost (1997$)		
capital	$ 300.0 million	partial system closure will be achieved as a stand-alone project at 10 newer mills
O&M	$ 0 million / yr	
fuel	- $ 28.6 million / yr	
Net economic cost		
lifetime NPV (1997$)	$32.4 million	using 10% discount rate
lifetime 1997$ /tonne	$ 5.3 / t CO_2	
Net financial cost		
lifetime NPV (1997$)	$ 200.1 million	using a pre-tax 40% discount rate

Note: a negative cost indicates a net savings. For net financial cost, a positive value represents the amount that would be required to make the action financially feasible from the industry perspective. A project may be financially feasible but not go ahead because considerations other than financial return also influence investment behaviour (eg. capital availability, risk).

Working toward system closure has the potential to substantially reduce ghg emissions, depending on the extent of the closure, which in turn determines the degree to which fossil fuel is used to heat water. This action assumes that water usage declines by 60% through partial system closure at ten newer mills, with a corresponding reduction in fossil fuels used for heating water. Since this is one of the major uses of energy in mills, the potential reductions in ghg emissions are significant.

While the analysis here calculates costs assuming that partial system closure of a mill occurs as a stand-alone project, in fact closure measures most often will be contingent on overall mill modernization projects due to the low return on investment for closure measures alone. The capital costs for system closure measures range from $20 million to $40 million (average of $30 million per mill), depending upon the type of mill and the extent of closure, but the total investment for mill modernization would be considerably larger. Full modernization projects - complete or nearly complete replacement of a mill with modern efficient technology - are likely to occur only when the financial situation of the pulp and paper industry improves markedly. The focus of this action is therefore on relatively newer mills since it these mills which will be most able to work toward system closure without the need for a full modernization program. These mills already have lower water use than the industry average.

Table 3.6.3
Regional Implications of Pulp and Paper Water Use Reduction

Region	Number of Mills	Mills Which Reduce Water Use	GHG Reduction in 2010 Mt CO_2	Net Economic Cost (10% discount rate) 1997$ mill	Cost Effectiveness 1997$ / Mt CO_2	Net Financial Cost (40% discount rate) 1997$ mill
Atlantic	19	1	0.03	5.3	8.8	20.8
Quebec	65	3	0.08	-8.2	-5.5	53.4
Ontario	35	2	0.06	-0.9	-0.8	37.3
Prairies	17	2	0.06	23.0	19.6	46.2
BC	27	2	0.09	13.2	7.6	42.5
Canada	163	10	0.31	32.4	5.3	200.1

Note: a negative cost indicates a net savings.

In general, the system closure technologies of the type required for this action need to be improved. In particular, advances in process design and control, contaminant separation, chemical regeneration, corrosion protection and energy management are needed to promote progressive closure of mill operations. Progressive closure measures are likely to implemented slowly due to concerns about degrading product quality and harming mill operations, for example by increased corrosion.

3.6.2 Action: Kraft Pulp Mill Black Liquor Integrated Gasification and Combined Cycle Cogeneration

ACTION:	***Adopt black liquor integrated gasification and combined cycle cogeneration (BLIGCC) technology in 3 kraft pulp mills by 2010***

Burning black liquor in recovery boilers provides a major source of energy in kraft mills; use of BLIGCC can increase power production by 200% compared to conventional steam turbines driven by black liquor combustion. Typically, full use of all of a kraft mill's pulping liquor in BLIGCC will produce excess electricity; if this can be sold, it will provide revenue to the mill.

Use of BLIGCC will have three effects on ghg emissions:

i it will eliminate purchased electricity - if the electricity is produced using fossil fuels this will reduce indirect emissions;

ii since BLIGCC will typically produce more electricity than is need by kraft mills, if the excess can be sold this will result in further reductions in indirect emissions if the sale replaces electricity produced using fossil fuels; and

iii BLIGCC produces less heat energy than the combustion of the black liquor so that additional fuel burning could be required to make up for the reduced steam, resulting in increased ghg emissions if fossil fuels are used. However, we assumed that BLIGCC will be implemented in conjunction with other modernization projects involving steam conservation, thus maintaining a balance in steam supply and demand. Thus, this action assumes that steam demands fall so that a make-up fuel is not needed.

At present, black liquor gasification is at the near-commercial demonstration stage. It is expected that with an accelerated approach one or more pilot projects could be in place by about 2002. A further 5 years would be needed to resolve technical problems. Thus, limited commercial use of the technology should be possible by 2010 with appropriate support. Aging of existing recovery and power boiler stock means that replacement or major overhauls will become due at many mills over the next 5-20 years, providing an opportunity to adopt black liquor gasification when it becomes commercially available. Steam demand will also decline over this period, providing a further attraction to move to BLIGCC. Thus, if successful implementation of the technology occurs by 2010 there could be substantial further direct and indirect ghg emission reductions in the following 10-20 years as the technology becomes more widely adopted (over 50 mills have recovery boilers).

A key factor in the estimate of costs is the future capital cost of a BLIGCC unit and whether is will be less or more than a conventional black liquor recovery power facility. The total cost for either of these is in the $120-140 million range but the incremental cost (or savings) of a BLIGCC unit compared to a conventional unit is highly uncertain. For this analysis we have assumed that a BLIGCC is marginally less expensive ($6-8 million less).

Table 3.6.4
Action Costs and GHG Impacts of Black Liquor Integrated Gasification Combined Cycle Cogeneration

	Estimate	Assumptions
Lifetime	20 years	in place by 2010
Incremental cost (1997$)		3 mills adopt BLIGCC by 2010
capital	- $ 23.6 million/yr	capital cost is less than for a black liquor recovery power plant
O&M and fuel	- $ 7.0 million / yr	assumes electricity purchases are zero
electricity	$56.9 million / yr revenue	assumes electricity sold at 4 cents per kWh
Mills Can Sell Electricity		
GHG impact		
lifetime ghg reduction	21.8 Mt CO_2 direct and indirect	
ghg reduction 2010	1.09 Mt CO_2 direct and indirect	
Net economic cost		
lifetime NPV (1997$)	- $ 621.6 million	using 10% discount rate
lifetime 1997$ / tonne	- $ 28.5	
Net financial cost		
lifetime NPV (1997$)	- $ 246.8 million	using a pre-tax 40% discount rate
Mills Cannot Sell Electricity		
GHG impact		
lifetime ghg reductions	4.36 Mt CO_2 direct and indirect	
ghg reduction 2010	0.22 Mt CO_2 direct and indirect	
Net economic cost		
lifetime NPV (1997$)	- $ 89.2 million	using 10% discount rate
lifetime 1997$ /tonne	- $ 20.4 / t CO_2	
Net financial cost		
lifetime NPV (1997$)	- $ 48.1 million	using a pre-tax 40% discount rate

Note: a negative cost indicates a net savings. For net financial cost, a positive value represents the amount that would be required to make the action financially feasible from the industry perspective. A project may be financially feasible but not go ahead because considerations other than financial return also influence investment behaviour (eg. capital availability, risk). Changes in emissions of CH_4 and N_2O are accounted for only partially.

Considerations related to the risk associated with adopting a new technology will likely play a more prominent role than financial benefits in mill decisions to invest in gasification. From a climate change perspective, the emission reduction benefit is increased substantially when the excess electricity can be sold to displace fossil-fuel based utility electricity.

This action applies only to chemical pulp mills since only these mills have recovery boilers. The estimates assume adoption of the technology at one average sized kraft mill in each of Ontario, the Prairies and the Atlantic provinces. Because BC and Quebec electricity is produced using hydropower, it is assumed that no indirect emission reductions will occur in those provinces if BLIGCC is adopted. This means that no net emission reductions occur with its application in these two provinces. In fact, there is no regional boundary to the utility market and BC and Quebec export to adjacent provinces where the marginal fuel for electricity is fossil fuel. From a national perspective, all power produced using renewable energy in BC and Quebec could be considered as displacing fossil fuel generated power. However, this possibility was not included in the analysis as it was assumed that adoption of 3 black liquor gasifier systems by 2010 is already an ambitious target.

Table 3.6.5
Regional Implications of Adopting Black Liquor Integrated Gasification Combined Cycle Cogeneration and Selling Excess Electricity

Region	Number of Chemical Pulp Mills	Assumed Adoption of Black Liquor Gasification by 2010	GHG Reduction in 2010 Mt CO_2	Net Economic Cost (10% discount rate) 1997$ mill	Cost Effectiveness 1997$ / Mt CO_2	Net Financial Cost (40% discount rate) 1997$ mill
Atlantic	7	1 gasifier	0.38	-87.7	-11.6	-50.4
Quebec	19	-	-	-	-	-
Ontario	11	1 gasifier	0.38	-116.7	-15.2	-66.5
Prairies	7	1 gasifier	0.33	-121.2	-18.6	-69.1
BC	17	-	-	-	-	-
Canada	61	3 gasifiers	1.09	-325.6	-14.9	-186.0

Note: a negative cost indicates a net savings.

3.6.3 Action: Kraft Pulp Mill Wood Waste Gasifiers for Lime Kilns

ACTION: Install wood waste gasifiers to fuel 10 kraft mill lime kilns, by 2010

Lime kilns are one of the major sources of ghg emissions in mills producing kraft pulp: at present, lime kilns in Canada use fossil fuels, accounting for roughly 10% of the energy used in producing kraft pulp and a higher proportion of the ghg emissions.

Table 3.6.6
Action Costs and GHG Impacts of Using Lime Kiln Wood Gasifiers

	Estimate	Assumptions
Lifetime	20 years	
GHG impact		
lifetime ghg reduction	6.2 Mt CO_2 direct and indirect	
ghg reduction 2010	0.31 Mt CO_2 direct and indirect	
Incremental cost (1997$)		
capital	$ 284.0 million	10 gasified wood lime kilns in place in place by 2010
O&M	$ 7.1 million / yr	
fuel	- $ 6.3 million / yr	assumes kilns use 25% fossil fuel, 75% gasified biomass, cost based on 2005 forecast energy prices
Net economic cost		
lifetime NPV (1997$)	$ 291.0 million	using 10% discount rate
lifetime 1997$ / tonne	$ 47.1 / t Mt CO_2	
Net financial cost		
lifetime NPV (1997$)	$ 286.6 million	using a pre-tax 40% discount rate

Note: a negative cost indicates a net savings. For net financial cost, a positive value represents the amount that would be required to make the action financially feasible from the industry perspective. A project may be financially feasible but not go ahead because considerations other than financial return also influence investment behaviour (eg. capital availability, risk). Changes in emissions of CH_4 and N_2O are accounted for only partially.

As combustion of wood wastes does not result in countable CO_2 emissions, switching to wood waste as a fuel for lime kilns will reduce emissions. Wood wastes cannot be used directly as a fuel source in kilns but wood waste gasification appears to be a feasible means of replacing fossil fuel. Wood biomass gasifiers to produce fuel gas for lime kilns is being applied at four mills in Europe and is consider a near commercial technology that could be applied in Canada between 2005 and 2010. De-rating of the lime kiln is possible depending on the biomass gas quality, and co-firing of gasified biomass and fossil fuel will be necessary in order to maintain stable lime kiln operation.

A key factor affecting future adoption of wood biomass gasification will be the availability of reasonably priced delivered wood wastes. As well, lime kiln loads may be too small in many or most cases for the use of biomass gasifiers to be economic. There are still a number of technical issues that need to be resolved before full commercial acceptability. Further research and demonstration of the technology is needed.

This action applies only to kraft pulp mills since only these mills use lime kilns. The assumed distribution of gasifiers is based on the distribution of kraft mills, current wood waste availability and the relative ghg emission reduction cost effectiveness of the action in each region. Roughly 5-15% of the current wood waste levels in each province will be used, for a total of about 0.5 million oven dried tonnes.

Table 3.6.7
Regional Implications of Using Lime Kiln Wood Gasifiers

Region	Number of Kraft Pulp Mills	Adoption of Wood Gasifiers for Lime Kilns, by 2010	Wood Residue Required mill ODt/yr	GHG Reduction in 2010 Mt CO_2	Net Economic Cost (10% discount rate) 1997 $ million	Cost Effectiveness 1997$ / Mt CO_2	Net Financial Cost (40% discount rate) 1997 $ million
Atlantic	4	1 gasifier	0.041	0.03	17.6	23.9	21.1
Quebec	10	2 gasifiers	0.078	0.06	31.0	33.7	39.2
Ontario	9	1 gasifier	0.054	0.03	26.0	40.9	28.8
Prairies	6	2 gasifiers	0.115	0.07	72.7	53.8	67.6
BC	17	4 gasifiers	0.216	0.13	143.7	56.5	129.9
Canada	46	10 gasifiers	0.503	0.32	291.0	47.1	286.6

Note: a negative cost indicates a net savings.

3.6.4 Action: Adoption of High-Intensity Dryers in Paper Mills

> ***ACTION:*** ***All new paper dryers purchased by paper mills from 2006 to 2010 will be high intensity dryers.***

This action is based on analysis using ISTUM. High-intensity dryers to dry paper are still in development but it is thought that they could be applied by 2006 if an effort is made to further their development and commercial application. For this action we assume that all purchases of paper dryers after 2005 will be of this technology - as existing dryers reach the end of their useful life they are replaced by high-intensity dryers. Use of the technology is assumed to reduce energy costs and it is also thought that the capital cost of the technology will be lower than that of conventional dryers. However, considerable uncertainty exists about both the capital costs and energy consumption of high-intensity dryers.

Table 3.6.8
Action Costs and GHG Impacts of Adoption of High-Intensity Dryers in Paper Mills

	Estimate	Assumptions
Lifetime	20 years	
GHG impact		
lifetime ghg reduction	6.0 Mt CO_2e direct and indirect	results derived using ISTUM; marginal fuel for electricity in BC and Quebec is hydro until 2013
ghg reduction 2010	0.21 Mt CO_2e direct and indirect	
Incremental cost (1997$)		high intensity dryers assumed to be $5-12 million cheaper than alternative dryers; O&M and fuel savings is an annual average - the actual savings vary over time depending on the time-path of the investment
capital	- $257.2 million	
O&M and fuel	- $26.0 million	
Net economic cost		
lifetime NPV (1997$)	- $ 516.3 million	using 10% discount rate
lifetime 1997$ /tonne	- $ 85.9 / t CO_2e	
Net financial cost		
lifetime NPV (1997$)	- $ 348.9 million	using a pre-tax 40% discount rate

Note: a negative cost indicates a net savings. For net financial cost, a positive value represents the amount that would be required to make the action financially feasible from the industry perspective. A project may be financially feasible but not go ahead because considerations other than financial return also influence investment behaviour (eg. capital availability, risk). Changes in emissions of CH_4 and N_2O are accounted for only partially

With this action, high-intensity dryers account for about 30% of dryers in the industry by 2010. This quick penetration rate is a function of the current age profile of the dryer stock and the serviceable life of dryers.

The regional differences shown in Table 3.6.9 reflect regional differences in the types of paper produced, the mix of fuels used in steam production and energy prices. Compared to the other regions, Ontario produces relatively much less newsprint which requires less energy for drying than does linerboard, coated paper and uncoated paper. As well, it uses more fossil fuels than most other regions to produce steam. For these reasons most of the emission reductions occur in Ontario.

Table 3.6.9
Regional Implications of Adoption of High-Intensity Dryers in Paper Mills

Region	% Share in Paper Production Capacity	GHG Reduction in 2010 Mt CO_2e	Net Economic Costs (10% discount rate) 1997$ mill	Cost Effectiveness 1997$ / Mt CO_2e	Net Financial Costs (40% discount rate) 1997$ mill
Atlantic	14	0.01	-39.2	-436.0	-30.6
Quebec	42	0.02	-180.7	-361.4	-138.9
Ontario	25	0.18	-244.7	-45.8	-137.9
Alberta	3	0.00	-7.2	-	-6.1
BC	16	0.01	-44.4	-555.0	-35.5
Total	100	0.21	-516.3	-85.9	-348.9

Note: Manitoba/Saskatchewan not included in the analysis because of the small size of their industries. No ghg impacts are shown for BC and Quebec because of the assumption that the marginal fuel for electricity production in these provinces is hydro, which has no emissions. Negative values represent net savings.

The analysis shown in Tables 3.6.8 and 3.6.9 is based on the assumption that reductions in the purchase of electricity in BC and Quebec result in no indirect emissions reductions because the marginal source of electricity is hydropower through to 2012. Changing this assumption so that the marginal fuel for utility electricity production in these two provinces is natural gas has almost no effect on the results. Most of the energy used for most dryers is provided by steam rather than electricity.

3.6.5 Action: Lignin Precipitation to Improve Recovery Boiler Operation

ACTION:	***Improved pulp liquor recovery boiler operation through lignin precipitation at 45 chemical pulp mills, creating biomass fuel for lime kilns***

Many chemical pulp mills are recovery limited, meaning that mill production is limited by the capacity of the recovery boiler to burn pulping liquor. This problem can be alleviated by removal of a portion of the organics or lignin from the black liquor by lignin precipitation. The precipitate can be used as a fuel either in the lime kiln or in a boiler as a replacement for purchased fossil fuel. Liquid fuel or "lignogel" can be produced from this precipitated lignin, and precipitation can be achieved with spent acid from a mill's bleaching plant. In a typical mill, precipitation of 10% of the lignin in the liquor could be used to displace up to 90% of the fossil fuel used in the lime kiln.

Lime kilns are one of the major sources of ghg emissions in mills producing kraft pulp: at present, lime kilns in Canada use fossil fuels, accounting for roughly 10% of the energy used in producing kraft pulp and a higher proportion of the ghg emissions. As combustion of biomass does not result in countable CO_2 emissions, switching to biomass as a fuel for lime kilns will reduce emissions.

There are about 61 recovery boilers in use today at chemical pulp mills in Canada. We assumed that, of these, about 45 are overloaded and would benefit from this action, with a resultant reduction in fossil fuel use in lime kilns. However, while the technology is considered commercially applicable, a first demonstration still is needed, preferably in a small operation at a cost of about $3 million. Thereafter, significant R&D could be required for further optimization.

Table 3.6.10
Action Costs and GHG Impacts of Improved Recovery Boiler Operation

	Estimate	Assumptions
Lifetime	20 years	assumes action fully implemented at 45 mills by 2005
GHG impact		
lifetime ghg reduction	4.3 Mt CO_2 direct and indirect	
ghg reduction 2010	0.22 Mt CO_2 direct and indirect	
Incremental cost (1997$)		
capital	$ 180.0 million	applied in 45 recovery boilers
O&M	$ 2.3 million / yr	
fuel	- $ 12.1 million / yr	uses forecast energy prices for 2000
Net economic cost		
lifetime NPV (1997$)	$ 87.7 million	using 10% discount rate
lifetime 1997$ / tonne	$ 20.2 / t Mt CO_2	
Net financial cost		
lifetime NPV (1997$)	$ 145.5 million	using a per-tax 40% discount rate

Note: a negative cost indicates a net savings. For net financial cost, a positive value represents the amount that would be required to make the action financially feasible from the industry perspective. A project may be financially feasible but not go ahead because considerations other than financial return also influence investment behaviour (eg. capital availability, risk). Changes in emissions of CH_4 and N_2O are accounted for only partially.

Table 3.6.11
Regional Implications of Improved Recovery Boiler Operation

Region	Number of Chemical Pulp Mills	Assumed Application to Recovery Boilers	GHG Reduction in 2010 Mt CO_2	Net Economic Cost (10% discount rate) 1997 $ million	Cost Effectiveness 1997$ / Mt CO_2	Net Financial Cost (10% discount rate) 1997 $ million
Atlantic	7	6 boilers	0.04	6.4	7.8	17.4
Quebec	19	11 boilers	0.05	10	10.1	31.3
Ontario	11	8 boilers	0.04	12.5	17.3	24.7
Prairies	7	6 boilers	0.03	16.6	30.7	21.2
BC	17	14 boilers	0.06	42.1	33.4	50.8
Canada	61	45 boilers	0.22	87.7	20.2	145.5

This action applies only to mills which produce chemical pulp. The assumed distribution of the action is based on the current distribution of recovery boilers, the share of energy consumption from pulping liquor in each province, and the relative ghg emission reduction cost effectiveness of the action across the regions.

3.6.6 Further Assessment of Forest Industry Emerging Technology Actions

Competitiveness, Economic and Social Implications

By their nature, the actions considered here are risky and costly, but also hold great promise to not only reduce ghg emissions but also reduce costs over the long run. As part of mill modernization they also imply a significant departure from the current operation of pulp and paper mills. The adoption of gasification entails considerable risks for the mills which pioneer the use of the technology at a commercial scale. If the excess electricity produced using BLIGCC in a pulp mill can be sold then this will add a significant revenue source to the mill which will help reduce total energy costs. Progressive systems closure in pulp and paper mills reduces the consumption of water, chemicals and energy and the discharge of material to the environment. Thus it reduces material, energy and effluent treatment costs. In the longer term it is a means to shift from large investments in end-of-pipe effluent treatment toward investments in improved process technologies, while at the same time reducing effluent discharges.

Changes in the long term needs of pulp and paper mills for purchased electricity, chemicals and other materials will have impacts outside the industry. The installation of BLIGCC at only 3 mills will reduce the industry's annual purchase of electrical energy by 0.3 petajoules in the Atlantic region, 0.3 petajoules in the Prairies and 0.7 petajoules in Ontario. This is equivalent to a reduction of about 0.1-0.2% in projected total end use demand for electricity in each region in 2010. If the mills can sell their excess electricity, which is a key factor in promoting the adoption of black liquor gasification, then about 5 petajoules of biomass-based electricity will be provided each year.

Because of the large investments involved with these emerging technologies and approaches, the direct and indirect economic and employment effects related to research, development, commercialization and implementation could be important. It is probable that much of the technology would be imported but the role for Canada in development, supply and use of the technologies is unknown. Longer-term effects on in-mill employment are also unknown.

Environmental and Health Impacts

The implementation of emerging technologies which increase the energy derived from biomass fuels, such as black liquor gasification and wood waste gasifiers, will offset fossil fuel consumption and the emissions associated with the combustion of these fuels. The adoption of emerging energy saving technologies, such as high intensity dryers in paper mills also will reduce fossil fuel requirements. Aside from reductions in ghgs, reductions in NO_2, SO_2, CO, VOC, and PM emissions will occur.

Lower fossil fuel use reduces cumulative or excessive concentrations of air emission pollutants. Reduced air emissions improve air quality, reduce acid rain, reduce odours, and can provide human and ecological health benefits (i.e., reduce human mortality and morbidity, plant and habitat destruction, etc.). Human health benefits can involve decreased susceptibility to lung infections, respiratory problems and immune deficiency to colds and bronchitis. Decreased fossil fuel emissions such as NO_2, SO_2 and PM can reduce damage to buildings and other structures of interest.

Environmental impacts other than those related to air emissions will also occur. System closure provides environmental benefits by reducing the consumption of resources and the discharge of effluent wastes, including organochlorines (AOX), total suspended solids, biochemical oxygen demand and colour. There are also potential adverse environment impacts from system closure activities. As system closure occurs, the effluent becomes highly concentrated and more toxic, thus raising questions of whether current primary and secondary effluent treatment systems can handle the increase and remain in compliance with effluent control regulations.

Extent of Interest in Emerging Technology Actions/Measures in Other Countries

Gasification technologies using a variety of fuels are being investigated aggressively in the United States. Issues related to biomass and black liquor gasification are a key area of energy-related research of the joint government-industry-academia Agenda 2020 for the pulp and paper industry, and several pilot facilities have been in operation for a number of years. This suggests that the technology may be an important element of any strategy to be promoted by the US government and the pulp and paper industry to reduce the sector's ghg emissions.

Further Analytical/Study Needs

Because these actions concern new or emerging technologies and processes that are still in their developmental or very early application stage, costs and technical specifications of a commercial application are speculative. More in-depth study would help to refine this information and provide a better indication of how applicable the technologies might be across Canada, given the current characteristics and age of mill technology stocks.

Relationship to Other Actions/Measures

Efforts to modernize and work toward system closure affects the impact of all other actions because such efforts will substantially reduce overall energy use and mean important changes in mill design. Most of the other energy and technology actions are incremental actions that could be undertaken to a large extent by themselves. While all of these other actions could still be considered, their individual impact on emissions would be reduced if they were applied in mills with partial system closure. Consequently, their cost effectiveness might decline.

BLIGCC complements systems optimization and other means to reduce steam needs - in fact, the BLIGCC requires a reduction in total mill steam demand to permit a balanced power/steam ratio for a mill. If this does not occur, then additional steam must be produced in the mill, which may require additional fossil-fired or biomass-fired boiler capacity. BLIGCC complements the action related to optimization of black liquor recovery boilers. While BLIGCC optimizes use of recovery boiler biomass, the other gasification actions require the use of wood wastes. To the extent that these actions require greater use of wood wastes, they need to be considered in combination with other fuel-switching actions to assess how the total assumed wood residue use compares to projected wood residue availability.

3.7 OTHER ENERGY OPTIONS

While most of the Table's analysis of emission-reducing actions focussed on the forest products industry, the Table had a broad mandate to consider all emission-reducing actions related to the forest sector. This includes the use of forest biomass for the production of energy outside the forest products industry, in order to reduce the use of fossil fuels. Possibilities include the use of biomass for electricity and space heating, on a variety of scales, and the use of biomass for liquid fuels. Time limitations prevented much work in this regard but one area of focus of the Table was the use of surplus wood residues for the production of wood-ethanol.

3.7.1 Action: Development of Wood Ethanol Production Facilities

ACTION:	***Commercial development of wood-ethanol technology leading to the development of 2 wood-ethanol plants by 2010***

This action is consistent with a recent recommendation of the BC Greenhouse Gas Forum, a multi-stakeholder group, which had consensus agreement that wood-ethanol potential should be explored. Following the recommendation there has been strong interest in the development of a commercial wood-ethanol facility in BC. In large part this is driven by a desire to find an economic use for the large quantities of surplus wood residues which are currently incinerated without energy recovery and create local air pollution concerns.

At present there are five technologies under development for producing wood-ethanol. Each is at a different stage of development and each has its strengths and weaknesses. None is commercially applicable today, unlike grain-ethanol technologies which are currently being used widely. We assumed that accelerated technological development would lead to establishment of two wood-ethanol facilities by 2010, each small-scale and with an output of 70 million litres per year. One would be in BC and the other in Alberta. The ethanol would be blended with gasoline to produce E10, a blend containing 10% ethanol.

Four criteria were used to assess the potential for siting a wood-ethanol plant. These were 1) the existence of a long-term and economic supply of whitewood waste (sawdust and shavings) in excess of 0.2 million ODt per year - this requires that there be a high local concentration of residue sources as transportation costs to access residues further afield can quickly become prohibitive; 2) the ability to derive value from waste lignin, a by-product of ethanol production (some of the lignin could be burned in the plant for energy), whether through sale to a local pulp mill for energy or through sale of excess electricity produced in the plant; 3) proximity to a petrochemical plant to blend the ethanol with gasoline; and 4) proximity to rail transportation and large potential ethanol markets.

Much of the current and future wood residue surplus in Canada is bark rather than the whitewood waste that an ethanol facility would require. Only BC and Alberta are expected to have sufficient quantities of whitewood residues in 2005-2010 to support the establishment of ethanol facilities, though the quantity that might be available in Alberta is questionable (see Table 3.2.3). Other sources of feedstock could also be used, including pulp and paper mill primary treatment sludge and fibre from fast-growing tree plantations, though these are speculative at present. We assume that there are three possible sites in BC (Prince George, Kamloops and Houston) and one in Alberta (Grande Prairie) that are most likely to have a sufficient feedstock supply and also satisfy the other three conditions. The most likely first location is probably Prince George.

Table 3.7.1

Action Costs and GHG Impacts of Wood Ethanol Production

	Estimate	Assumptions
Lifetime	20 years	
GHG impact		commercial application by 2005-2010, with 2 plants in place by 2010, ethanol used in E10 blend, net emission reductions include reduced gasoline emissions, minor CH_4 and N_2O emissions from ethanol use, and indirect emission reductions from selling excess biomass-based electricity to replace electricity from natural gas
lifetime ghg reductions	7.3 Mt CO_2e direct and indirect	
ghg reduction 2010	0.36 Mt CO_2e direct and indirect	
Incremental cost (1997$)		ethanol replaces gasoline in E10 blend, priced using 2010 real crude oil price of 1997$26 per barrel, excess electricity produced using lignin is sold at 4 cents per kwh
capital	$ 160.0 million	
O&M and fuel	- $ 11.8 million / yr	
Net economic cost		using 10% discount rate
lifetime NPV (1997$)	$ 49.4 million	
lifetime 1997$ /tonne	$ 6.8 / t CO_2e	
Net financial cost		
lifetime NPV (1997$)	$ 118.7 million	using a pre-tax 40% discount rate

Note: a negative cost indicates a net savings. For net financial cost, a positive value represents the amount that would be required to make the action financially feasible from the industry perspective. A project may be financially feasible but not go ahead because considerations other than financial return also influence investment behaviour (eg. capital availability, risk)

The benefit of wood-ethanol lies in the fact the CO_2 emissions from biomass burning are assumed to be CO_2 neutral if the biomass originated from sustainably managed forests. Thus almost all of the emissions associated with gasoline are reduced when it is replaced by ethanol in a E10 blend. As well, we assume that the plants produce more electricity than they need and are able to sell it to replace utility electricity produced using natural gas. This results in an additional indirect emissions reduction.

Aside from reducing net ghg emissions, the use of an E10 blend in place of gasoline reduces emissions of carbon monoxide by 8-30% and also reduces VOC (both of which are contribute to urban smog), reduces emissions of toxic air pollutants such as benzene, toluene and xylene by 5-15% and may reduce tailpipe emissions of fine particulate matter. These reductions should have positive impacts on human health. A secondary environmental benefit is that use of wood residues for wood-ethanol rather than disposing of them by incineration reduces aesthetic problems of smoke and reduces local particulate emissions.

3.8 SUMMARY OF ENERGY ACTIONS AND CROSS-CUTTING ISSUES

3.8.1 Summary of Energy Actions

Table 3.8.1 summarizes the 17 actions the Table analyzed in its assessment of ways to reduce ghg emissions, ranking them in terms of cost effectiveness. As discussed in the next section, the impacts of the actions are not necessarily additive. The cost effectiveness results are based on an assessment of net economic costs and use a 10% discount rate to calculate the net present value of all costs and savings. A negative number indicates the ghg reduction is achieved with net savings.

Table 3.8.1
Summary of Forest Sector Energy Actions

Action	Type of Measure	Cost Effectiveness 1997$ / t CO_2e	Direct and Indirect GHG Emission Reduction, 2010 Mt CO_2e	Estimated Incentive for Realization 1997$ mill
1 Adoption of high intensity driers - paper mills	emerging technology	-85.9	0.21	0
2 Improve maintenance/use of existing auxiliary equipment - pulp and paper mills	energy efficiency	-64.1	0.36	0
3 Improve maintenance and use of existing steam-producing equipment - pulp and paper mills	energy efficiency	-61.3	0.85	0
4 Adopt high energy-efficiency auxiliary technologies - pulp and paper	energy efficiency	-38.5	0.65	0
5 Improve process thermal integration - pulp and paper mills	energy efficiency	-31.8	1.25	0
6 Black liquor integrated gasification and combined cycle cogen - 3 pulp and paper mills (mills sell excess electricity at 4 cents per kWh)	emerging technology	-28.5	1.09	0
7 Adopt energy efficient process technologies - pulp and paper	energy efficiency	-24.1	2.68	839
8 Optimize recovery boilers - 35 pulp and paper mills	fuel-switching	-15.2	0.39	65
9 Increase wood waste cogeneration - 12 pulp and paper mills (mills sell excess electricity at 4 cents per kWh)	fuel-switching	-11.1	2.45	247
10 Fuel-switching - lumber and panelboard mills	fuel-switching	-5.4	1.51	356
11 Increase number of hog fuel boilers - 12 pulp and paper mills	fuel-switching	-3.4	1.33	111
12 Modernization of hog fuel boilers - 35 pulp and paper mills	fuel-switching	-2.6	0.48	155
13 Adopt high energy-efficiency tech - lumber and panelboard mills	energy efficiency	4.4	0.33	57
14 Reduce water use through progressive system closure - 10 pulp and paper mills	emerging technology	5.3	0.31	200
15 Development of 2 wood-ethanol plants	other energy	12.3	0.36	134
16 Lignin precipitation / improve recovery boiler operation - 45 pulp and paper mills	emerging technology	20.2	0.22	146
17 Biomass gasification to feed lime kilns - 10 pulp and paper	emerging technology	47.1	0.31	287

While actions may have a net savings based on an evaluation of net economic costs, the net financial costs as perceived by industry can be quite different. As explained in Section 3.2, we used a 40% discount rate to determine net financial costs from the industry perspective for each action, and used this as the basis for estimating the direct incentive to realize the action. **We emphasize that our estimates of the incentives needed for financial feasibility are crude and do not account for the variety of other impediments that may prevent investments in energy-efficiency and fuel-switching actions, even if they are financially feasible.** These include capital limitations, problems with selling excess electricity and the risk associated with making large long-term investments, especially those involving new or emerging technologies.

In general, the energy efficiency actions tend to be the most cost effective, with net savings achieved over the life of the action. The fuel-switching actions also have estimated net savings, as do two of the emerging technology actions though there clearly are substantial impediments to adoption of these technologies which have not been included in the cost estimates. Foremost is the cost of accelerating the development of the technologies to the point at which they can be commercialized. Commercialization itself will be a difficult process because companies are unlikely to be willing to invest large sums in unproven technologies. Government support of some kind will be required to accelerate development and reduce the financial risk of implementation. Note that the results for the wood waste cogeneration and black liquor integrated gasification combined cycle cogeneration actions are based on the assumption that mills can sell excess electricity at a price of at least 4 cents per kWh, something that generally is not possible at present. Without removal of this impediment, these two actions would require substantial incentives to make them financially attractive.

3.8.2 Cross-Cutting Issues and Summary of Net Emission Reduction Potential

Each of the actions described in this Chapter was assessed in isolation, relative to BAU energy use and ghg emissions. However, the net effect of the actions will be less than the sum of their individual effects for two reasons. First, there will be technological complementarities and conflicts among actions when they are implemented together in a mill. Second, while the energy efficiency actions will reduce the need for wood residues, many of the other actions require increased use of wood residues. Therefore, the projected declines in future wood residue availability discussed in Section 3.2.2 could limit implementation of some actions. We address both of these issues below.

Complementarities and Conflicts Among Actions

In some cases sequencing of the actions could be important - an action may make most sense in a mill before or after another action has taken place. As well, in practice many of the actions will interact if implemented at the same time in the same mill. Thus, in a given mill, the actions are not necessarily additive, for a variety of reasons. Partly this is because a decision to pursue one course of action in a mill means that another does not make sense. At the same time, some of the actions could interact with positive synergies - doing them together could result in a greater ghg impact than doing them separately. A more likely possibility is that doing two or more actions at the same time in the same mill will result in lower emission reductions than the sum of the individual reductions.

Concerns about the additivity of the action impacts are most relevant when actions are considered at the mill level. They are likely to be less of an issue when the actions are considered at a national or even regional level. This is because most of the actions do not apply to all mills. Instead some fraction of mills in any given region is assumed to be affected by each action, meaning there is less chance of overlap of actions at any one mill. Nevertheless, it is incorrect to simply sum the ghg emission impacts across the actions. The net effect of implementing all the actions will be less than the sum of the actions because of conflicts and interactions between actions. In addition to effects on emission reductions, implementing actions together will also affect costs. The most likely effect may be to reduce total costs compared to the sum of individual action costs.

A review of the actions suggests that most pairs of action are complementary - they could be done together in a mill. This is certainly true of the energy efficiency actions in relation to one another and to the other actions. However, while most actions can be done simultaneously, their combined net impact will be lower than the sum of their individual impacts. This sort of effect is difficult to assess without modelling the interactions between technologies when actions are implemented together. The results of the ISTUM analysis provides some guidance here, though only some actions were assessed using this tool. For example, analysis using ISTUM for the pulp and paper industry shows that combined adoption of more efficient process technologies, adoption of more efficient auxiliary technologies and increasing the use of hog fuel boilers results in emission reductions in 2010 of 4.2 Mt CO_2e or about 0.5 Mt CO_2e lower than the sum of the individual impacts of these actions (see Tale 3.8.1). This is because reducing a mill's steam needs through the energy efficiency actions and reducing ghg emissions from steam by using more hog fuel both effect boiler technologies and use. Thus these three combined actions have a 10% lower ghg emission reduction than the sum of the individual action reductions.

There are also a few cases where actions clearly conflict - two actions would not be done at that same time in the same mill. These conflicting actions are:

- hog fuel boiler modernization and increasing the use of hog fuel boilers;
- recovery boiler optimization and black liquor integrated gasification combined cycle cogeneration;
- recovery boiler optimization and lignin precipitation in recovery boilers; and
- biomass gasification for lime kilns and lignin precipitation with the resulting precipitate used as lime kiln fuel.

We were not able to provide a full assessment of the interaction of the various actions in terms of their combined impact on emissions reductions and costs in the industry as a whole. However, we think it likely that the total ghg impact of the actions will be 25-50% lower than the sum of the individual impacts.

Residue Supply Shortages

In total, the surplus supply of residues in Canada is fairly large but in some parts of the country it is very limited. The energy efficiency actions often reduce the amount of residues needed. On the other hand, fuel-switching actions tend to require large quantities of biomass fuel. Thus a full assessment of the energy-related actions require that we consider how each one affects wood residue use as this will help to determine what combination of actions will be feasible, given our projection of future residue availability. **As noted a number of times in this chapter, there is the possibility that other sources of biomass fuel - logging and sorting yard wastes, pulp mill waste biomass, and agricultural and municipal wastes - could be developed for extensive use as energy in forest industry mills. We did not examine this possibility and it is a key area for further research.**

Table 3.8.2 summarizes the projected effect of each action on residue use in 2010, and also shows the projected BAU residue surplus in 2010. While the residue effects are not fully additive, their sum by region does suggest where residue availability could be a limiting factor when compared to the projected surplus residues. The energy efficiency actions will result in a substantial reduction in demand for residues by as much as 3.6 million ODt. However, the other actions, especially the fuel-switching actions, require large quantities of residues. In total, we estimate that the increased residue use as a result of the actions will be a maximum of 3.2 million ODt in 2010, the same as the projected surplus in that year.

However, at a regional level there are substantial variations, and it is important to keep in mind that transportation of residues beyond about 100 km is not economic at present. In the absence of additional wood-waste fuel sources, our estimates suggest that residue shortages could be a problem in Ontario and the Atlantic region but will be most problematic in the Prairie region (mainly Alberta). In Alberta, it may be possible to access some economically priced residues from eastern BC. Although Quebec will not face an absolute shortage of residues, the fact that almost all of the surplus is bark, a relatively low quality and expensive fuel, means that in practice there could be difficulties with supply.

Table 3.8.2

Projected Effect of the Energy Actions on Wood Residue Demand, 2010, million ODt / yr

Action	Region					
	Atlantic	Quebec	Ontario	Prairies	BC	Canada
Projected BAU use of residues for energy in pulp, paper and saw mills, 2010	**1.42**	**1.87**	**1.34**	**1.40**	**2.78**	**8.81**
FOREST INDUSTRY ENERGY EFFICIENCY ACTIONS						
1 Process thermal integration - pulp and paper mills	-0.22	-0.28	-0.23	-0.18	-0.66	-1.57
2 Energy efficient process equip. - pulp and paper mills	-0.12	-0.10	-0.13	-0.14	-0.62	-1.11
3 Maintenance/use of auxil. equip. - pulp and paper mills	-	-	-	-	-	-
4 Maintenance/use of steam equip. - pulp and paper mills	-0.13	-0.20	-0.10	-0.11	-0.37	-0.91
5 Energy efficiency auxil. equip. - pulp and paper mills	-	-	-	-	-	-
6 Energy efficiency equip. - lumber and panelboard mills	-	-	-	-	-	-
FOREST INDUSTRY FUEL-SWITCHING ACTIONS						
7 Hog fuel boiler modernization - pulp and paper mills	0.15	0.30	0.15	0.08	0.20	0.88
8 Increased number of hog boilers - pulp and paper mills	0.43	0.32	0.11	0.20	0.42	1.48
9 Recovery boiler optimization - pulp and paper mills	-	-	-	-	-	-
10 Wood waste cogeneration - pulp and paper mills	-	0.18	0.44	0.88	0.55	2.05
11 Fuel-switching - lumber and panelboard mills	0.21	0.05	0.39	0.21	0.66	1.52
FOREST INDUSTRY EMERGING TECHNOLOGIES						
12 Progressive system closure - pulp and paper mills	na	na	na	na	na	na
13 Black liquor integrated gasification combined cycle cogeneration - pulp and paper mills	-	-	-	-	-	-
14 Biomass gasification for lime kilns - pulp and paper mills	0.04	0.08	0.05	0.11	0.22	0.50
15 High intensity dryers - paper mills	-	-	-0.03	-	-	-0.03
16 Lignin precipitation - pulp and paper mills	-	-	-	-	-	
OTHER ENERGY ACTIONS						
17 Wood-ethanol	-	-	-	0.20	0.20	0.40
Maximum increase in residue demand above BAU level due to actions, 2010 (note the actions are not fully additive)	**0.36**	**0.35**	**0.65**	**1.25**	**0.60**	**3.21**
Projected BAU surplus residues, 2010	**0.09**	**1.19**	**0.13**	**0.14**	**1.64**	**3.20**

Note: a negative number indicates a projected decline in demand for residues relative to the projected BAU residue use. A dash indicates zero or very little effect on residue demand is expected.

One of the major draws on residue surpluses will be wood waste cogeneration. This action was derived by examining biomass cogeneration projects that are already on the drawing board and could proceed rapidly if economic and other barriers were removed. We assumed that the proponents of these projects have concluded that their future residues requirements can be met, though we did not account for these projects in the BAU projection of residue surpluses.

The combined actions would use a significant share of the large BC residue surplus but 1 million ODt or more would still be unused in the province in 2010. The current high use of residues for energy in the BC industry means that the energy efficiency actions in the province's pulp and paper industry cause a large reduction in residue demand that is roughly offset by the fuel-switching actions.

Overall, in some regions implementation of the energy efficiency actions to reduce residue demand will be crucial for helping to balance the increased use of residues as a result of fuel-switching. However, reductions in residue demand are likely to be less than shown in Table 3.8.2 for the energy efficiency actions because of the interactions among these actions. Even with reductions in residue use resulting from increased energy efficiency, it is likely that full implementation of the fuel-switching actions will not be achievable in Atlantic Canada, Ontario and the Prairies given the expected future availability of residues. This means that the fuel-switching actions will not achieve their full potential emission reduction in these regions.

Net Emission Reduction Potential

Table 3.8.3 summarizes the action emission reductions by region and shows our rough adjustments to account for complementaries and conflicts among actions, and likely residue shortages. To account for the interaction among actions we lower the ghg reductions by 33%. To account for likely residue supply problems in Atlantic Canada, Ontario and the Prairies we assumed that some fuel-switching would not occur in these regions. Specifically, we assumed that fuel-switching in lumber and panel mills would not occur in these three regions, and that addition of new hog fuel boilers would not occur in Ontario and the Prairies. These adjustments still mean that there would likely be a residue shortage in the Prairies (mainly Alberta) but we assumed that the large surplus of residues in north central and north western BC could be accessed economically by Alberta mills.

Table 3.8.3

Summary of Emission Reduction Impacts by Region, 2010, Mt CO_2e

	Atlantic	Quebec	Ontario	Prairies	BC	Canada
Forest industry energy efficiency actions	1.02	1.49	1.96	0.71	0.95	6.12
Forest industry fuel-switching actions	0.80	0.76	1.07	2.13	1.41	6.17
Forest industry emerging technology actions	0.49	0.19	0.69	0.48	0.28	2.14
Forest industry total	**2.31**	**2.43**	**3.73**	**3.32**	**2.64**	**14.43**
Adjustment 1: reduction by 33% to account for complementarities and conflicts among actions	-0.77	-0.81	-1.24	-1.11	-0.88	-4.81
Adjustment 2: reduction to account for projected residue supply problems in some regions	-0.21	-	-0.33	-0.70	-	-1.24
Adjusted forest industry total	**1.33**	**1.62**	**2.16**	**1.51**	**1.76**	**8.38**
Other energy action (ethanol)	-	-	-	0.18	0.18	0.36

Overall, the adjustments suggest that implementation of the actions as a package could reduce pulp, paper, lumber and panelboard mill direct and indirect emissions by about 8.4 Mt CO_2e in 2010, given the appropriate incentives and efforts to address impediments. In comparison, direct and indirect energy-related emissions of these mills were 20.1 Mt CO_2e in 1990 and are projected to be 23.1 Mt CO_2e in 2010 in a BAU world (see Tables 3.1.1 and 3.1.2). Thus the reduction represents a 27% decline below 1990 direct and indirect emissions. In Section 5 we present a subset of the actions which we believe should be part of the core National Implementation Strategy.

4.0 CARBON SEQUESTRATION OPTIONS

4.1 INTRODUCTION

A sink is an activity or process that removes CO_2 from the atmosphere and a source is an activity or process that adds CO_2 to the atmosphere. This Chapter deals with land-use, land-use change and forestry options related to increasing forestry sinks and reducing forestry sources for those forest-related biological sources and sinks that are or may be included under the Kyoto Protocol. As currently written, the Kyoto Protocol does not consider the whole Canadian forest, or even a major component of it like the "managed" forest. Instead, the Protocol includes only three specific activities related to forests - reforestation, afforestation and deforestation (RAD) since 1990. Thus changes in the carbon in Canada's total forest have no bearing on Canada's efforts to meet its Kyoto commitment. However, it is useful to understand the total forest carbon budget - the annual flows between carbon pools - and the extent to which it can be affected by disturbances such as wildfire.

The carbon in Canada's forest is influenced mainly by the age distribution of its trees, which in turn depends on the history of natural and anthropogenic disturbances affecting the forest. Forest growth removes carbon from the atmosphere through photosynthesis, retaining it for decades or centuries. Young fast-growing trees store relatively small amounts of carbon - they are small carbon reservoirs or pools - but have a rapidly increasing annual carbon absorption rate - they are rapidly growing sinks. At least two or three decades of growth, and sometimes much longer depending on the tree species, usually are required to reach maximum annual sink capacity. The older the forest the greater the amount of carbon it stores. However, as a forest ages it becomes more susceptible to insects and disease and may face a greater likelihood of wildfire. Fire and decomposition of dead organic matter emit carbon back to the atmosphere. A large part of the carbon ends up in the soil, which can be a significant reservoir.

Canadian Forest Service scientists and other experts have developed a Carbon Budget Model of the Canadian Forest Sector (CBM-CFS2). The model shows that, in 1990, Canada's forest stored about 86,000 Mt of carbon, of which close to 85 percent was in forest soils and dead organic matter, with the remainder in biomass. The model suggests that Canada's forest was, on average, a sink of about 205 Mt C/yr in 1920-89 (Kurz and Apps, 1999) but became a source in the 1980s, with an average annual loss to the ecosystem of about 69 Mt C per year in 1985-89. If conversion of some of this carbon to long-term storage in forest products is taken into account, the net average annual emissions were about 45 Mt C/yr at the end of the 1980s, or a source of 165 Mt CO_2-equivalent each year. This important change from a large sink to a large source was due mainly to increased wildfire and insect infestations since the 1970s, the cause of which is uncertain. Changes in harvesting played only a minor role as the area harvested annually was far lower than the area affected by natural disturbances. The forest is likely still a carbon source today, and if high natural disturbance rates continue, perhaps due to global warming, it could remain a carbon source for a considerable time into the future.

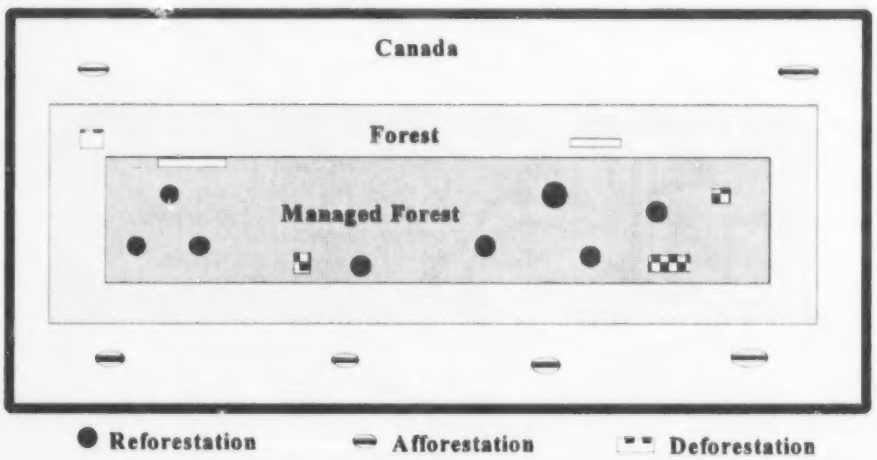
The large changes in the annual carbon flux (a change from a sink to a source of carbon) of the Canadian forest as a whole reflect to a large extent the effect of natural phenomena on forest lands where there is no direct human activity. Such areas are <u>not</u> the focus of the UN Framework Convention on Climate Change or the Protocol. Instead the focus of the Convention is on the ghg emissions and removals that result from human activity. The Protocol is even more limited in its focus and considers only carbon stock changes associated with two activities that take place within the forest, reforestation and deforestation, and an activity that takes place outside the existing forest area, afforestation (see Figure 4.1). Only activities that have occurred since 1990 are considered. Canada will get credit for removals in 2008-12 associated with reforestation, afforestation and deforestation, and will receive a debit for emissions in 2008-12 associated with the activities.

Canada's measurement requirements to account for RAD will be completely clear only after more international negotiation. A key uncertainty is how the three activities will be defined - different definitions can result in vastly different sizes of sinks or sources. As well, agreement is needed on what measurement systems will be acceptable and what carbon pools will be included (i.e., just above-ground biomass or all carbon pools including soils). Finally, the Protocol allows for discussions on what additional direct human-induced activities in the agricultural soil and land-use, land use change and forestry categories should be added to the RAD activities. The potential contribution of forest sinks to meeting Canada's Kyoto Protocol target will depend in large part on the outcome of these negotiations.

Canada's view is that what the atmosphere sees is of utmost importance, and that any approach should foster the enhancement of sinks and the reduction in sources. The current Protocol, by limiting activities, by including activities without a sink term, and by specifying how the changes would be measured, does not fully account for what the atmosphere sees, nor does it credit and thereby provide incentives for good forest management practices that ensure the sustainability of existing forests. It creates an imbalance between sinks and sources and, depending upon interpretations, can actually penalize a country that sequesters more carbon than it emits, as shown by some of the presentations at the recent SBSTA workshop in Rome. There is considerable uncertainty about the definitions of many of the key terms used in describing the role of carbon sequestration in the Kyoto Protocol, as well as the possible role of additional activities that might be allowed subject to future negotiations. Canada has proposed that the criteria established to address these uncertainties should:

- be based on sound science;
- promote other environmental objectives related to land-use;
- maintain symmetry and consistency in the treatment of land-uses; and
- promote rather than undermine the objectives of the Convention.

Figure 4.1
Forest-Related Activities Included in the Kyoto Protocol



The "Kyoto forest", the forest which is included in the accounting for the Kyoto Protocol emission reduction commitments, includes land affected by reforestation which presumably (under the Canadian definition) occurs only within the managed forest area, deforestation which can occur at any point in the forest, and afforestation which occurs on non-forest land. These activities are included only if they have occurred since 1990.

Canada and a few other countries have proposed a "managed forest" approach as an alternative to the current RAD provisions of the Protocol, in order to address some of the current imbalances in the Protocol. This approach would provide a full accounting of changes in carbon stock within the specified managed forest area, and would ensure that all forest management activities that result in carbon stock increases or decreases are accounted for.

Because of the uncertainties surrounding the outcome of the negotiations, the domestic carbon sequestration options are presented in three separate sections: activities that are currently in the Protocol and have relatively high certainty of being defined in a way such that options are relevant (i.e., afforestation); activities that are currently in the Protocol but have relatively uncertain definitions (i.e., reforestation and deforestation); and activities that are not currently in the Protocol but that are being considered for inclusion (e.g., all forest management activities on the managed forest). We also include in the latter category a discussion of the storage of carbon in forest products. The current IPCC guidelines (i.e., for reporting on ghg inventories under the UNFCCC) treat harvests as an emission in the year of harvest. However, it is not clear if these guidelines will be applied under the Protocol, and even if they are used (as opposed to the adoption of new ones), they may be modified to better reflect the actual carbon flows when trees are harvested and made into forest products. If carbon stored in forest products is included under the Protocol, then this has implications for potential strategies to enhance carbon stocks.

When a truly long term perspective is adopted (>100 years), it becomes evident that forest sinks have only a modest role to play in addressing climate change, since there are biophysical and practical limits to how much carbon can be stored in forests and forest products. Forest sinks cannot provide a permanent solution to the problem of anthropogenic climate change, and activities to enhance forest sinks should be considered an interim measure to supplement measures aimed at reducing ghg emissions. While the total store or stock of carbon in forests may be permanently increased, after a time, the net removal of CO_2 will equal zero, so that there is no further sink uptake.

It should also be noted that while the Forest Sector Table agrees that measures to protect and enhance forest sinks should be part of Canada's climate change strategy, there are differing views among Table members about whether, or to what extent, credit for such activities should be used to offset ghg emissions.

What is the BAU for RAD?

Since carbon sinks and sources are not included in the *Energy Outlook*, which is used as the BAU (or more accurately "policy as usual") emissions baseline, we provide an estimate of the BAU for sinks and sources under the Kyoto Protocol. Because of the definitional uncertainties noted earlier, there is, in fact, a set of BAU scenarios that correspond to the different potential negotiation outcomes related to both definitions and activities included under the Protocol. In terms of the Protocol, the BAU estimates are what would be available to be offset against Canada's emissions target in the first (or subsequent) commitment period(s), without additional investment or changes in policy.

The discussion in this Chapter focuses largely on either increasing the amount of carbon that is stored on a given area and/or increasing the area that is forested relative to the BAU (this includes reducing the area deforested). Sequestration options require a set of policies or programs to be put in place to increase the net carbon sequestered in the first and subsequent commitment periods.

4.2 CURRENTLY IN PROTOCOL WITH HIGH CERTAINTY OF DEFINITION - AFFORESTATION

The term 'afforestation' has not yet been defined for the purposes of the Kyoto Protocol, and international agreement on a definition is not likely for several years. However, it should be noted that under virtually all sets of definitions being discussed, planting of trees on marginal agricultural land as described here would be included under the Protocol, although it might be defined as reforestation rather than afforestation. Two possible definitions for afforestation are as follows:

Canadian proposal: a change in land-use that, through the establishment of a stand of trees, forms a forest

IPCC definition: planting of new forests on lands which, historically, have not contained forests.

Closely related to the IPCC definition of afforestation is its definition of reforestation: 'planting of forests on lands which have, historically, previously contained forests but which have been converted to some other use'. Under the IPCC definitions the actions described below would be considered a mixture of afforestation and reforestation although ascribing specific areas of newly planted forest to one or the other could be difficult in instances where the historical land cover and land use changes are not known with certainty. **The Canadian proposed definitions are used in this Options Report but it must be kept in mind that these may not be accepted.** Implications of the uncertain negotiating outcomes are described further below.

The BAU estimates of afforestation presented in the Sinks and Forest Sector Table Foundations paper indicated a potential of 1-2 Mt CO2/year in the first commitment period, based on very rough estimates of current rates of tree-planting and changes in land-use. Further consideration of these estimates has led us to conclude that most of these areas would not be considered afforestation under the Kyoto Protocol, or would be too difficult to monitor and verify. Therefore the BAU estimate for afforestation is assumed to be zero.

The Forest Sector and Sinks Tables assessed a variety of afforestation actions based on tree species used, type of afforestation and region, as shown in Table 4.2.1. Background information for the assessment of these actions was provided by five studies commissioned for the Table on afforestation potential in Canada, and a sixth study on design and implementation options for afforestation programs (see Annex A). It should be noted however, that the results discussed here are not directly comparable to those in the studies, as further internal analysis was done that required various some changes in assumptions and modifications to the analysis. The results shown in Table 4.2.1 are subject to many uncertainties and are of low to medium confidence. The carbon sequestration, costs and cost effectiveness are very sensitive to the assumptions used, of which the most important are tree growth curves, areas afforested, planting schedules, the value of the activities given up when the land is afforested and discount rates used for financial flows (10%) and carbon flows (no discounting). Tree growth in the early years after planting and growth rates on plantations are areas of great uncertainty, and there is a need to compile and synthesize date for various species from provincial and other databases across Canada.

The calculated net cost of afforestation should include planting costs, the opportunity cost of the land, protection costs and the transaction costs associated with afforestation programs and measuring, monitoring and verifying carbon sequestration. It should also include the value of various possible uses, including for forest products and bioenergy, and the value of the carbon and a wide variety of environmental benefits and uses such as soil protection, water quality improvements and habitat enhancement. Information on the values of most of these benefits is uncertain, in large part because of uncertainty about the future value of carbon, uncertainties about market opportunities for use of the wood for forest products and how harvesting and forest products carbon will be dealt with in the Protocol, and the difficulty of quantifying the environmental benefits and uses. Our analysis is based only on assessment of planting and opportunity costs - thus the cost effectiveness results are not based on the true net cost of afforestation since not all costs and benefits are included.

Overall, the results indicate that a concerted effort to afforest 50,000 ha in fast-growing species over 5 years (2001-2005) will result in 1.3 Mt CO_2 in 2010. Planting 793,000 ha over 15 years (2001-2015) in slower-growing species results in sequestration of 0.8 Mt CO_2 in 2010 though this estimate is of low confidence, reflecting considerable uncertainty in tree growth in the first few decades after planting. While we assumed that planting could start as early

as 2001 at a modest level (12,200 ha of traditional species, and 10,000 ha of fast-growing species) that builds over time (61,000 ha per year of traditional species in 2006-2015), this is a very optimistic assumption and will require an immediate and intensive effort to achieve. Delaying start-up to 2002 or 2003 significantly reduces carbon sequestration in the first commitment period but may be necessary. Differences in cost effectiveness and sequestration across actions reflect regional differences in species planted, growth curves, planted areas, and planting costs.

The planting levels of the actions exceed by far any previous afforestation effort in Canada. Planting on recently harvested lands exceeds 400,000 ha per year in Canada, almost all of it on publicly owned forest land, so that a great deal of planting expertise and knowledge can be called upon for afforestation. However, as discussed below, the real challenge with an afforestation effort of the level proposed in the actions is the complexity and difficulty of attracting thousands of individual landowners of marginal agricultural and other land.
Note that to achieve the total sequestration of 2.1 Mt in 2010, the full planting effort need not be undertaken (ie. planting need only occur in 2001-2009) but planting the annual target over the full 15 year period results in a substantial increase in sequestration in the years subsequent to the first commitment period. Also note that annual carbon sequestration after 20 or 50 years due to planting traditional species will be quite substantially higher than it is in 2010. Whereas it is 0.8 Mt CO_2 in 2010, by 2020 it is around 2.9 Mt CO_2, and in 2050 it is about 7.5 Mt CO_2. Over the 2000-50 period, carbon sequestration averages over 4 Mt CO_2 per year from planting traditional species.

Of particular note in Table 4.2.1 is the difference in the carbon sequestration and cost of planting fast-growing tree species compared to planting larger areas in slower growing species. Compared to the latter, fast-growing plantations are much more cost-effective and result in significantly more sequestration in the first commitment period. Over a longer time period, fast-growing plantations are less favourable because the trees have much shorter lives. Planting fast-growing species might often be done with the goal of harvesting the trees in 12-15 years and this raises complicated and as yet unresolved issues about how harvesting of afforested areas will be treated in the Protocol.

Table 4.2.1
Summary of Afforestation Actions[1]

Action	Annual Planting Target[2] ha / yr	Planting Period	Total Planting ha	Cost Effectiveness[3] 1997$ / t CO_2e		Carbon Sequestration[4] Mt CO_2e	
				2008-2012	2000-2050	2010	2000-2050
Fast-growing plantations	10,000	5 years	50,000	22.2	na[5]	1.31	na[5]
Prairie shelterbelts	13,000	15 years	169,000	140.7	3.7	0.15	29.0
BC block plantations	13,000	15 years	169,000	452.5	2.4	0.04	35.2
Prairie block plantations	20,000	15 years	260,000	114.6	3.0	0.37	71.4
Eastern block plantations	15,000	15 years	195,000	144.9	2.3	0.22	68.6
Total			843,000			2.08	

1 The sequestration and cost effectiveness estimates for the first commitment period are considered to be of low confidence. Other estimates are considered to be of medium confidence.

2 All planting starts in 2001. With the exception of the fact-growing species action, all planting ramps up to the annual planting target by 2005. For the fast-growing species action, full annual planting starts in 2001.

3 The costs include planting and maintenance costs only; not included are the cost of protection and the transaction costs associated with afforestation programs and carbon measuring, monitoring and verification systems. Also not included are revenues from the harvest and use of the tree, and the value of environmental benefits.

4 Only above- and below-ground tree biomass carbon is included in the net sequestration estimates for the fast-growing plantation action and the Prairie and BC actions. The Eastern Canada actions also include soil and non-tree biomass carbon. Emissions from the use of fossil fuels in planting are accounted for in the estimates.

5 For the fast-growing species action, the assumption is that harvesting, if it occurs, will happen at age 13-15 years and the area is replanted. Over the 2000-50 period, the net carbon sequestration will then depend on how harvesting of afforested areas and carbon in the resulting forest products are treated in the Protocol.

The details of the analysis for each action are described below in Sections 4.2.3 to 4.2.7. Before presenting the details for each action it is important to review the analytical issues and uncertainties in the analysis, and the assumptions that were used. This is the subject of the Section 4.2.1. Section 4.2.2 describes impediments to the afforestation actions and policy considerations. The review of the afforestation actions closes in Section 4.2.8 with a

brief assessment of other issues, including competitiveness, economic and environmental implications of afforestation, the use of planting programs in other countries with Kyoto emission reduction or limitation targets, and further analytical needs to improve our understanding of afforestation actions. The final section, 4.2.9, presents stakeholder views on the actions. Some Table members and stakeholders have expressed considerable concern about the uncertainties surrounding afforestation.

It should be noted that the analysis here presents the perspective of the Forest Sector and Sinks Tables. However, much of the focus of the actions is on agricultural land and the actions need to be assessed further from the perspective of the agricultural sector. A comparison of these actions to the carbon sequestration potential of shrubs and non-woody crops on agricultural land as well as practices to increase agricultural soil carbon would be useful. While these latter activities are not currently in the Kyoto Protocol, efforts are underway to add them.

4.2.1 Analytical Issues, Uncertainties and Assumptions

Types of Afforestation and the Use of Afforested Areas

For the purposes of the analysis, the Forest Sector and Sinks Tables distinguished three types of afforestation based on their different effects on existing land uses and the types of land that typically may be involved with each (see Table 4.2.2). The discussion here focusses only on the first two - block plantations and shelterbelts. A block plantation is a relatively large area devoted to trees while shelterbelts involve rows of trees such as those planted around farm field perimeters. It should be noted that shelterbelts would likely not be included under Canada's definition of afforestation.

There are significant differences between block plantations and shelterbelts in terms of their potential future uses (other than for carbon sequestration) and potential future carbon debits, the economics of afforestation, species selection and policy considerations. These issues are discussed below.

Table 4.2.2
Types of Afforestation and Potential Uses

	Block Plantation (relatively large block of trees)	**Shelterbelt (rows of trees)**	**Tree Planting (small scale scattered tree planting)**
Target land type	Probably marginal agricultural land, but may target un-used or under-utilized good quality agricultural land where productivity is highest	Agricultural land where soil erosion exists or other benefits may be derived	Any land type
Magnitude of effect on current land use	For individual land-owners, requires a large-scale conversion of land use	For individual land-owners, land-use conversion would be minimal or moderate	Little or no effect on current land use
Purpose/Use	Carbon Fibre for products or bioenergy Environmental uses - restoration of degraded and fragmented forests, biodiversity, habitat enhancement, aesthetics, improved water quality and quantity, soil conservation and protection	Carbon Improve crop yields, reduce energy use in buildings Environmental uses - aesthetics, improved water quality and quantity, soil conservation and protection, protection from wind and sun, aesthetics, improve water quality and quantity, noise reduction	Carbon Reduce energy use in buildings Environmental uses - aesthetics, improved water quality and quantity, soil conservation and protection, protection from wind and sun, aesthetics, improve water quality and quantity, noise reduction

A key uncertainty in the analysis of afforestation is the future use of the afforested areas. Choices about the purpose(s) of afforestation in any given area will help to determine who will be interested in afforestation, their degree of participation, the level and structure of incentives required to encourage involvement and the time path of future carbon credits and debits that they (and Canada) will be responsible for. It will also influence the choice of species used and the environmental, social and economic effects of the afforestation. All of these issues are discussed further in this section and in the following section. Here, the variety of possible uses are described.

Clearly, carbon sequestration and the creation of carbon reservoirs is a primary goal in the context of the Kyoto Protocol and the Framework Convention on Climate Change. Broadly speaking, there are two other classes of use, one related to harvesting for forest products or bioenergy and the other related to environmental or other goals which generally do not involve harvesting. In many cases, there could be multiple end uses. In general, an intent to achieve goals beyond just carbon sequestration will likely be the most successful approach to the development of afforestation programs. Such goals would vary from location to location.

In the context of the Protocol, harvesting and the assignment of the associated carbon credits and debits is a difficult issue and one that is still unresolved at the international level. This is discussed further below. There are important differences between block plantations and shelterbelts in this regard. Block plantations are more likely to be harvested at some point in the future, while the removal of shelterbelts generally is not anticipated. If the afforested area remains permanently in forest then eventually the net annual carbon sequestration will fall to zero as the carbon stock stabilizes (i.e., net removals through decay will equal growth). For the slowest growing species this could take over 100 years.

In addition to the possible economic benefits of harvesting, there are a wide variety of environmental non-market benefits that can result from afforestation, on areas that may or may not be harvested in the future. These include restoration of degraded or fragmented forests, wildlife habitat enhancement, biodiversity protection and enhancement, improved water quality and quantity and soil conservation and protection. Other potential benefits, especially for shelterbelts, are noise reduction, protection of buildings from the wind, sun and cold (which can reduce energy consumption for space heating and cooling), aesthetic improvements and improvements in crop yields.

Uncertain Negotiating Outcomes

International agreement may not be reached until COP6 (fall 2000) or later on the definitions of afforestation and reforestation, and on which carbon stock components will be counted for the purposes of determining compliance with the Protocol. It seems clear that block plantations will be included in the Protocol irrespective of the definitions of afforestation and reforestation which emerge from future negotiations. It also seems likely, though less certain, that shelterbelts may be included. The IPCC definitions and the Canadian suggested definition both mean that tree planting as defined in Table 4.2.2 probably would not be included in the Protocol unless the planting qualifies as establishing a forest.

In terms of carbon stocks, it is clear that carbon sequestration from above-ground tree biomass is included, but there is some uncertainty as to whether carbon sequestration in soils and below-ground biomass will be included. In the analysis by the Forest Sector and Sinks Tables below-ground tree biomass carbon was estimated and soil carbon was included where it could be estimated. Another issue related to carbon stocks is whether carbon sequestration on a given area of land, in the absence of afforestation, must be accounted for. Prior to afforestation the land may be either a sink or a source because of the vegetation already on the land and how it changes over time. It is possible that this existing sink (source) would have to be subtracted (added) to the carbon sequestration resulting from afforestation so that only the net increase in carbon due to afforestation is accounted for in assessing credits. The action analysis does not take this into account.

Future negotiations also will determine whether activities which enhance agricultural soil carbon sequestration will be included. This is of relevance for the analysis of afforestation as the inclusion of agricultural soils creates the potential for competing actions and policies to promote carbon sequestration on the same agricultural land either from afforestation or from agricultural soil sequestration. For example, changes in agricultural practices to improve soil carbon might also reduce soil erosion so that shelterbelts would provide less of a benefit (they would still provide benefits such as improved crop yields).

A fourth key uncertainty is how harvesting of areas afforested since 1990 will be treated in the Protocol. At issue is whether harvesting will result in debits, and if so, how the carbon stored in forest products is counted and who owns the credits when the products are traded.

A final major uncertainty is related to the guidelines, rules and procedures for measurement, monitoring and verification of carbon sequestration that will be determined by future international negotiations. The costs of these activities will vary according to the requirements, the type of afforestation and afforestation policies. These costs were not assessed by the Forest Sector and Sinks Tables.

Land Availability and Participation Rates

The biophysical suitability of land is not a limiting factor for afforestation in Canada. Instead the potential for afforestation is a function of financial and other factors. Thus the portion of the suitable land that actually will be made available for block plantations and shelterbelts is very difficult to estimate as it depends on a range of factors including current land uses and their financial returns, ownership, owner characteristics and motivations, and location. It also depends on factors related to the afforestation program implementation such as awareness, promotion and credibility.

In some parts of the country there are areas of publicly owned marginal agricultural land which could be used for afforestation. In general, however, relatively little agricultural land is publicly owned and the afforestation actions presented in this Options Report are aimed primarily at privately owned land, especially marginal agricultural land - the policies to implement afforestation on public land would be much different than those discussed here. To access private land, plantations and shelterbelts will require participation of thousands of heterogenous private landowners. This means that the impact of afforestation programs will ultimately be determined through a bottom-up process in which thousands of individual owners of farms and other land make the decision on where, when and if they wish to participate. It is the participation rate (number of landowners, area per landowner) that will determine the total land made available. It also will determine when the land will be made available, which affects the planting schedule, and therefore affects how quickly carbon is sequestered.

In the analysis of all but one of the afforestation actions (the fast-growing plantation action is the exception), we assumed the following relatively quick ramp-up in the planting schedule will occur.:

2000	program start-up
2001	20% of annual planting target
2002	40% of annual planting target
2003	60% of annual planting target
2004	80% of annual planting target
2005	100% of annual planting target
subsequent years to 2015	100% of annual planting target.

Even with significant incentives to landowners and widespread publicity, involvement in afforestation is likely to proceed slowly at first, as programs and policies are implemented, financing mechanisms developed, landowners and others learn about opportunities, technical advice is developed and made available, rules for carbon accounting are developed and nursery stock is made available. To take these factors into account we have assumed that planting will start in 2001 at a relatively modest level. Some Table members, as well as external reviewers, stressed that start-up in 2001 was a very optimistic assumption. For example, a 2001 starting date for planting would typically require a two-year lead time for provision of seedlings (i.e. in 1999). This is not likely to happen, and suggests that planting might not start until 2002/2003 at the earliest in some regions, given the time that would be needed to first obtain participation of landowners.

Determining likely rates of participation in afforestation is no easy matter and requires an assessment of the up-front costs and benefits to landowners, future costs and benefits, and their personal preferences and goals related to current and future land use. In trying to determine participation rates and the land that will be made available there are two key questions: 1) what incentives do landowners need to participate? and 2) how will the incentives be provided? The incentives that landowners will require may not be only financial, but also could include technical assistance, and information on the impact of afforestation on the land.

There will also be landowners who simply will not be interested in afforestation - for example, some farmers may have no interest in afforestation because their family has been farming for many generations, or because they do not wish to be locked into long term use of their land for forests. Such non-biophysical and non-financial constraints could be considerable.

The land that each landowner will make available will be a function of average land holding and individual owner decisions about what portion of their land they will afforest. Afforestation based on a lot of small plots owned by many people is likely to be more expensive than larger plots involving fewer landowners, though incentives for afforestation could be structured to encourage large, contiguous blocks of land. This could be done by providing incentives for groups of landowners to organize cooperatives.

Afforestation Costs

We started our afforestation analysis by deciding on actions for afforesting areas of land considered ambitious but realistic. Given a target level of afforestation in terms of area, and the characteristics of the land and landowners likely to be involved, there will be a certain level of cost that will be required. How these costs are financed (eg., with government funding, revenue from carbon credits, funding from companies interested in using wood, etc.), how participants in afforestation other than landowners can be involved, the types of incentive mechanisms that might be used, and other issues related to afforestation program design are discussed in the following section on policy considerations.

While financial concerns are not the only considerations of landowners, in order to secure their participation many will have to be compensated for the costs of planting and maintaining block plantations and shelterbelts. From the perspective of the landowner, there are three costs (the benefits and potential revenues are discussed in the next section).

1 Landowners sometimes earn revenues from their land which will be lost when afforestation occurs - there is an opportunity cost of afforesting the land. This is especially true of farmers who may have crops on the land or use it for grazing, though the primary focus of afforestation is more likely to be on lands that are not currently being used for agricultural purposes and so earn little revenue. Compensation for opportunity costs, whether paid by governments or by others interested in afforestation, could be in the form of a one-time payment, or through an annual land rental payment. While the present value of these two forms of payments might be equal, they may have different effects on landowners and one may be preferred over the other depending on the targeted landowners. From the perspective of a need to maintain carbon stocks, one concern about annual payments is that the landowner may come to rely on them, and once they are stopped he or she may choose to cut the trees and not replant (ie. deforestation), which would result in a carbon debit. On the other hand, annual payments may be attractive because they could convince landowners to treat trees as a crop. In contrast, one-time up-front payments may attract landowners with a longer-term interest in maintaining the forest. Whatever the form of the payment, a commitment to maintaining the land in permanent forest is crucial.

   Payments for conservation easements are one way to ensure a permanent commitment. Such easements could require that the land remain forested, or it could require the use of sustainable forest management practices in accordance with provincially established silvicultural guidelines. The easement would be permanent and would not change with change in ownership of the land, an important consideration in some parts of the country where land ownership changes are fairly frequent (10-20 years). Easements may be opposed at a local government level because they may reduce the economic activity and property taxes associated with the land.

2 The establishment and maintenance of forests entails costs related to site preparation, acquisition of seedlings, planting, fertilization if necessary, and follow-up activities such as weeding.

3 Finally, afforested areas face the risk of being fully or partially destroyed by fire, pests and windthrow. Fire and pest protection could have a quite significant cost. At present it is difficult if not impossible to obtain insurance for these risks but if large scale afforestation effort occurs then risk insurance may become more readily available. The risk of catastrophic losses to plantations in the short run is likely to be ameliorated by the fact that the forests will be easily accessible, relatively small and relatively young.

In the actions analysis we show estimates based only on opportunity and planting costs. We did not quantify the cost of forest protection. Establishment and maintenance costs are relatively easy to quantify based on widespread experience with reforestation costs in Canada. They typically range from $1,000 per hectare to $1,500 per hectare but they can be much higher in some cases - eg. $3,600 per hectare for planting fast growing hybrid poplar. These costs are spread out over several years and the present value is calculated using a 10% discount rate.

Opportunity costs are much more difficult to quantify and there was some divergence of opinion among Table members as to the appropriate values to use. Opportunity costs will vary significantly from location to location, according to the use and productivity of the land, and they may also vary depending on the magnitude of agricultural support programs offered. There is little information on the value of the uses, if any, of the land that most likely would be offered for afforestation. Some guidance can be taken from considering average per hectare farm profits, appraised land values and average farmland values. These sources suggest that annual rental values for farmland are on the order of $100-300 per hectare per year across the country. There are reasons to think that the annual opportunity cost for planting forests would be much lower than this. First, much of the focus of the plantation actions discussed here is on marginal agricultural land and much of this land likely is not being used currently for agricultural purposes. Second, non-agricultural landowners usually will not earn any direct revenue from their land. Finally, there are many farms which have an annual land rental value well below the average, and they may be most likely to participate in afforestation.

These reasons imply that, while the average opportunity cost is not likely to be zero, it could be relatively low. There are also likely to be important regional variations. Some Table members suggested that a significant amount of land might be made available at an opportunity cost of zero or close to zero in Eastern Canada. This reflects the relatively high proportion of land that could come from owners who already have woodlots on their land and who are familiar with forests. In contrast, in the Prairies most of the land is likely to come from owners with more purely agricultural experience and land uses so that opportunity costs could be higher than in Eastern Canada.

In the absence of any definitive information, we made the ad hoc assumption that the annual opportunity cost of the afforested land is $10 per hectare per year. This is roughly equivalent to a land value of $100-125 per hectare. For Western Canada we did sensitivity analysis to assess the effect of using an opportunity cost of $100 per hectare per year. For Eastern Canada we assess the sensitivity of the estimated cost effectiveness to an opportunity cost of $50 per hectare per year. Since fast-growing species may be planted on higher quality land, we assumed a somewhat higher annual opportunity cost of $25 per hectare year. This is at the low end of the range of annual land rental payments that have been made for hybrid poplar plantations in eastern Ontario ($25-30 / ha / yr) and southern BC ($100-300 / ha / yr). The present values of the $10 / ha and $25 / ha annual opportunity costs are calculated using a 10% discount rate over a 25 year period.

A fourth cost of afforestation is the transaction cost associated with developing and administering afforestation programs, and assessing the associated carbon credits and debits. **We have not attempted to estimate these transaction costs, though they could be substantial.** In total, the afforestation actions analyzed by the Forest Sector and Sinks Tables involve about 800,000 hectares over 15 years. By comparison, average farm sizes across Canada range from about 75 to 125 ha in Eastern Canada and BC, and 300 to 450 ha in the Prairie provinces. If individual landowners who participate provide 10-100 ha each, the afforestation actions would require involvement of roughly 8,000 to 80,000 landowners across the country. Recruitment and support of this many landowners will involve a sustained well-resourced effort that is beyond the current capacity of any existing government agency. However, the involvement of partners such a wood-lot owner associations and other non-governmental organizations to help deliver regional programs could be an effective approach.

The cost of measuring, monitoring and verifying carbon sequestration and possible emissions could be large. While most of these costs might be borne by governments, it is possible that some of the costs would be borne by landowners or others involved in afforestation.

Choice of Species and Tree Growth Curves

Given the land made available for tree planting, a further key determinant of sequestration is the choice of species. Species traditionally used for forestry, and for which seedling stock is relatively abundant, have relatively low sequestration rates in the Canadian climate, though their growth in plantations is very uncertain. Anecdotal evidence suggests that spruce and pine in plantations in Canada could reach peak annual growth in 25-50 years - this is much faster than the 40-75 years typical of unmanaged stands of these species. Faster growing species such as hybrid poplar can reach peak annual carbon sequestration rates in 10-25 years. The fastest growing tree and shrub species can take as little as 5-10 years.

Since a primary goal of afforestation will be carbon sequestration, choosing species which maximize sequestration will be an important criteria, though different species would be chosen depending on whether the goal is maximum carbon in a short time period, or maximum carbon over a longer period, and also what other goals are important. For the former goal, fast-growing species would be chosen. For the second, slower growing traditional species would be used. Where other purposes for the trees are also important then specific species for these purposes would be chosen. For example, use in forest products or for bioenergy would likely involve only one or a few species while a goal of forest restoration or habitat enhancement would require a more diverse set of locally prevalent species. With a mix of uses, a balanced species selection will be needed. Choice of species should also reflect other concerns - eg. those related to biodiversity, on which Canada has made international commitments. In the afforestation action analysis we show a fast-growing species plantation action as well as regional plantation actions which use traditional species.

We did not assess the impact of using shrub species in afforestation efforts. Such species could be a cost-effective approach and further analysis needs to be done in this area. Shrub species currently represent a major focus of the Prairie Farm Rehabilitation Administration Shelterbelt Centre. However, it is unlikely that these would be considered afforestation under the Protocol.

Whatever the species chosen, a serious difficulty in estimating sequestration is the lack of good information on growth curves for trees in plantations. The difficulty is compounded by the lack of good data on plantation growth in the first two decades after planting, the key period for determining the impact in the first commitment period. These difficulties mean that we consider the sequestration estimates for the first commitment period to be of low confidence. However, because our knowledge of tree growth after the first two decades is much better we have medium confidence in our estimates over a longer period such as 2000-50.

The growth curves used in the analysis are from a variety of sources including provincial governments and previous work on afforestation potential. The use of various sources meant that curves for different regions/species were not always consistent though we attempted to ensure as much consistency as possible. We tried to use growth curves that account for the fact that afforestation often will involve relatively intensive management on relatively good quality land (even though it may be marginal for agricultural purposes) so that growth will be fairly rapid compared to unmanaged natural forests. Table 4.2.3 summarizes the mean annual incremental growth for several representative species used in the analysis. As can be seen, growth rates in the first decade of growth vary much more than the average annual growth rates over 50 years though the latter are much more reliable estimates than the former.

Figure 4.2 shows the growth curves used for three species. Several key points should be noted about the curves. The first is that annual growth in the early years is slow for the two traditional species shown (i.e. the curves have a low slope) and that it is not until 15 or 20 years after planting that growth becomes sufficiently fast to allow substantial annual carbon sequestration. Second, annual total growth, and therefore carbon sequestration, can vary widely at a given point in time depending on the species chosen (i.e. the slope of the curves at a given age can differ markedly for different species). Finally, for the purposes of the Kyoto Protocol, carbon credits in the first and subsequent commitment periods will be calculated as the difference in the volume at the end a period and volume at the beginning of the period, irrespective of total volume. In other words, what counts is not the total volume at a given point in time, but the change in the volume over specified periods.

Table 4.2.3
Growth Curve Mean Annual Increments of
Representative Tree Species Used in Afforestation Analysis
m^3 / ha / year of bolewood

	Mean Annual Increment	
Region/species	Age 10	Age 50
BC Coast Douglas-fir	0.4	10.9
BC Southern Interior lodgepole pine	0.4	4.0
BC Interior aspen	0.2	3.0
Prairie white spruce	0.4	3.1
Prairie aspen	1.8	3.0
Eastern white and black spruce	0.9	4.7
Eastern red pine	2.3	5.2
Hybrid poplar - good sites[1]	13.2	0.8

1 Hybrid poplar stands are assumed to start to break-up by age 30 so that by age 50 the mean annual increment is very low. In practice, hybrid poplar stands would be harvested after 12-15 years. If left, the total site carbon could continue to grow depending on the succession of other species.

Future Harvesting and Deforestation of Afforested Areas

An important uncertainty about afforestation is how carbon will be counted if trees are removed from an afforested area. If the area is harvested and not replaced by a new forest, or is otherwise deforested, then it seems clear that a debit will result for that area, since deforestation is included in the Protocol. At a national level, if an equal area is planted then it will sequester an amount of carbon over time that is roughly equivalent (depending on species chosen) to the deforestation debit. Thus, over time there would be no net effect though the time path of the credits (which occur over a long time) and debits (which occur over a short period) needs to be kept in mind, and there would be an impact on net cost. Note also that achieving no net effect over time means accepting a permanent commitment to maintaining, at a national level, a given total afforested area, though its location in the country could change over time.

Alternatively, if the area is harvested and replaced by a new forest, then the issue is whether or not harvesting of afforested areas results in a carbon debit in terms of the Kyoto Protocol. One view is that, since the activity of harvesting is not explicitly included in the Kyoto Protocol, then there will be no debits. An alternate view is that once the land enters in the Kyoto forest (the area subject to reforestation, afforestation and deforestation since 1990) then any changes in the carbon stock on the land, whatever the cause, are included in the Protocol. This difference of opinion still needs to beresolved internationally.

If the harvesting does count as a debit, then there will need to be international agreement on appropriate accounting for storage of carbon in forest products, including who receives the credit for the stored carbon after the forest products are traded. Storage of carbon in forest products likely would mean that the debit resulting from the harvest would be less than the carbon sequestration that had occurred prior to the harvest. If the harvesting does not count as a debit, then one possibility is that credits from any particular site may cease after the first rotation, since there is no net additional sequestration over and above the maximum volume at the time of harvest.

Irrespective of how harvests or carbon in forest products are treated in the accounting, using the harvest to provide fibre for new processing facilities that would not otherwise be constructed in the BAU world will add to Canada's baseline fossil-fuel emissions. The increase in emissions because of these new facilities would have to be accounted for and would offset some of the afforestation carbon credits.

If the wood is used for bioenergy (fuel-switching) then the fact that CO_2 emissions from burning sustainably-produced wood are not counted in assessing a country's net ghg emissions becomes important. The reason why they are not counted is that the emissions from burning will be balanced by growth. Over the cycle of tree growth, harvest and burning, there will be no net emissions, implying that the carbon sequestration should only be counted as a credit if the emissions from burning the wood are counted as a debit. Where a new forest is planted, as with afforestation, this further implies that only carbon credits for the first planting would be received - subsequent sequestration from planting and emissions from burning would balance and would provide neither carbon sequestration credits nor emission debits.

At this point there are varying opinions domestically and internationally on these issues which will only be resolved through international negotiations. Resolution will hopefully occur by 2001. The greater likelihood that block plantations will be harvested as compared to shelterbelts means that these issues are of much greater significance for the former, especially when fast-growing species are used. The use of fast-growing species means that these issues will be important as early as the first commitment period. Note, however, that trees in shelterbelts eventually die, which may raise the same issues as harvesting, unless the shelterbelt becomes an uneven-aged stand in permanent tree cover.

In the long-run, net carbon sequestration benefits over and above carbon storage in forest products will only occur on lands that are permanently converted to forests. Where the land is only temporarily converted to forests, the ultimate deforestation debit will in all likelihood cancel out the previously obtained afforestation credit. In other words, a temporary conversion of land to forests will produce long-term carbon credits only to the extent that the credits are recognized for the storage of carbon in forest products. These credits are not included in our analysis since they are not part of the Kyoto Protocol at present. Thus, based on the Kyoto Protocol as it now stands, temporary afforestation simply 'borrows' carbon credits against future debits.

Assessing the Cost Effectiveness of Afforestation

For emission-reducing actions, cost effectiveness is measured as the net present value of lifetime costs of the action over the lifetime emissions reduction. The application of this approach to carbon sequestration poses problems related to the dynamic and long term impacts of afforestation actions. These actions are characterized by large up-front costs and carbon sequestration benefits which are a function of time. The carbon benefits are initially low, and this will certainly be true in the first commitment period, but they can become very substantial after several decades. As well, the 'lifetime' of the action is unclear. Using different time periods in the cost effectiveness calculation can give very different results. Accordingly, we decided to present two sets of estimates as was shown in summary Table 4.2.1. Both use the full cost of afforestation but one uses only the carbon sequestered in the first commitment period while the other uses the total carbon sequestered over 2000-2050. The second set does not account for the possible reconversion of land back to agricultural uses (deforestation) and the carbon debits that would then result, nor does it account for the effects on carbon of harvesting followed by regeneration of the forest. This is especially relevant for the fast-growing plantation action.

The long time periods involved also raise the issue of discounting the physical carbon, just as dollar values are discounted. Following the advice of the Analysis and Modelling Group, we have not discounted the carbon sequestered, though the largest annual sequestration benefit from afforestation could come 30 or more years in the future, depending on the species chosen and the planting schedule. By not discounting, the assumption is that the benefit of carbon sequestered in the future is the same as carbon sequestered now. There are two related aspects of this assumption. First, it means that, in terms of slowing climate change, sequestering carbon well into the future has the same impact on global warming as does sequestering in the near future.

The second aspect concerns the optimal way to make investments to reduce Canada's net emissions in the near term (ie. in the next 10-20 years), and especially to meet Canada's commitment for 2008-12. This is a question of determining the most cost effective investments in emissions reduction and sequestration, a key goal of the National Implementation Strategy. When cost effectiveness is calculated using sequestration over a lengthy period, and carbon is not discounted, the effect is to increase the cost effectiveness of sequestration actions relative to other actions, even though the sequestration could be relatively less cost effective in terms of helping to achieve Canada's target in the first few commitment periods. Another point of view is that afforestation is a hedge against more costly emission reduction actions that may be necessary in the future as initial relatively low cost actions are exhausted. The argument here is that, while apparently costly relative to other actions that could be initiated in the short to medium term, in the longer term afforestation will prove useful, but only if the action is taken now.

4.2.2 Impediments to Afforestation and Policy Considerations

Impediments to Afforestation

Each afforestation action faces similar impediments. The major impediments are summarized here, based in part on the discussion in the previous section:

- Negotiation outcomes, including the definition of afforestation and what carbon stocks will be counted, are uncertain. As well, there is a possibility that shelterbelts may not be included in the agreed-upon definition of afforestation - this will not be known until late 2000, at the earliest.
- Afforestation has a significant up-front cost for planting and maintenance, as well opportunity costs for the land diverted to growing trees. In contrast, benefits from using the trees for purposes other than carbon will occur in the future, perhaps not for three or four decades if slower growing species are used.
- There will be significant transaction costs to develop, implement and operate afforestation programs, including the systems needed to measure, monitor and verify sequestration and emissions.
- While Canada has a very large area of land that could be afforested, the land actually available for afforestation is likely much more limited. This is, in part, a function of market opportunities available to landowners and the level of incentives provided.

General policies and mechanisms to overcome these impediments generally do not differ from one afforestation action to another, and so we summarize them here rather than repeating them for each action. While this section describes various policies and mechanisms, the Forest Sector and Sinks Tables emphasize that more analysis is required to specify detailed afforestation program characteristics, targets and costs. The scale of the afforestation actions being considered here far exceeds any previous Canadian and most international efforts, and a prudent approach is to start at a modest scale with a focus on the most cost effective opportunities, and expand as experience is gained. As already explained, we include a moderate ramp-up period (2000-2005) to account for the time it will take to start up afforestation programs. This will also allow some time for experience to be gained, but an even slower approach could be chosen.

Mobilization of a Variety of Participants in Afforestation

The above discussion of participation rates and costs focussed on landowners since it is their land that will be planted. However, when considering how best to encourage afforestation, we need to consider both the potential revenues and other benefits of afforestation, and the potential motivations and roles of a variety of possible participants in afforestation efforts other than landowners (see Table 4.2.4). While commercial considerations and returns are one major motivation of involvement of many participants, it should be borne in mind that many other potential motivations exist. Examples of possible afforestation activities are presented in Figure 4.3 to highlight the range of values, uses and scales of afforestation that could occur.

Table 4.2.4

Participants in Afforestation Efforts

Participant	Potential Roles	Motivations	Requirement for Involvement	Afforestation Program
Participants whose land will be affected				
1 Farmers (including woodlot owners)	Provide land, may be involved in establishment and management	Financial return or at least no financial loss, maintain or improve the land (eg aesthetics, soil conservation, biodiversity, forest restoration)	A financial return at least equal to current revenue from land, if any, after accounting for risks; clear indication that land will be improved	Block plantations, shelterbelts, tree planting
2 Other landowners (eg recreational owners), including woodlot owners	Provide land, may be involved in establishment and management	Maintain or improve the land (eg aesthetics, soil conservation, biodiversity, forest restoration)	Clear indication that land will be improved; compensation for planting costs	Small block plantations, shelterbelts, tree planting
Participants who act as intermediaries				
3 Brokers, managers	Connect interested parties; may manage plantations; may provide some investment	Financial return	Financial return at least equivalent to other possible investments, after accounting for risks; carbon trading system	Block plantations
4 Investors with only financial motivations	Investment	Financial return	Financial return at least equivalent to other possible investments	Block plantations
Participants with a direct interest in the carbon, wood or environmental benefits of afforestation				
5 Federal and provincial governments	Investment (via incentives, favourable tax treatment); establish standards, carbon trading system, establish measurement, monitoring, verification systems	Help meet Canada's emission reduction commitment; rural employment, maintain or improve the land (eg aesthetics, soil conservation, biodiversity, forest restoration)	Cost effective (relative to other potential actions) and politically acceptable; clear indication that land will be improved	Block plantations, shelterbelts, tree planting
6 Companies, municipalities (may also own the land)	Investment (and favourable tax treatment in case of municipalities)	Carbon to offset their own emissions	Cost effective; recognition of the carbon as a legitimate offset for their emissions	Block plantations, shelterbelts, tree planting
7 Forest products companies, energy companies (may also own the land)	Investment, management	Supply of fibre for existing or potential uses	Supply that is economic relative to other supply sources (existing timber for forest products companies; other energy sources for energy companies)	Block plantations, shelterbelts
8 Municipalities, environmentally concerned citizens, ENGOs	Some investment, planting labour and other "free" services	Aesthetics, environmental concerns (biodiversity, soil conservation, reducing climate change, habitat)	Clear indication that environmental goals will be met	Shelterbelts, tree planting, block plantations (?)

In the previous section it was made clear that the single greatest impediment to achieving afforestation actions is likely to be achieving the necessary participation rates. **If we assume that the landowner bears all of the three costs described above then the total cost represents the level of incentive that will have to be provided to him or her to participate in afforestation, in the absence of any benefits from the afforestation.**

There are likely to be differences between block plantations and shelterbelts in the magnitude of the incentive required. Block plantations generally will require a much larger area commitment from individual landowners than will shelterbelts. The latter generally will occur on a relatively small part of a farm. In contrast, the scale of block planting might result in a farm losing its farm status, with a consequent loss of favourable tax treatment under current regulations. This implies that larger or different incentives may be needed for block plantations than for shelterbelts but we have not taken this into account in the analysis.

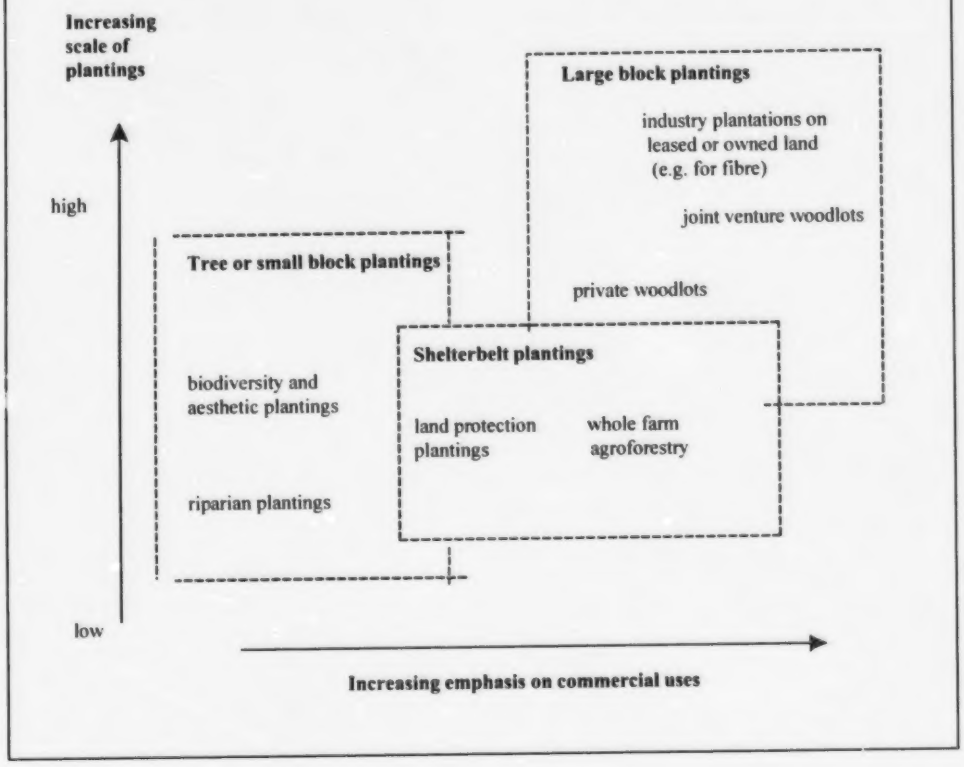
One way for the incentive to be disbursed is for governments to pay all of it, whether in the form of direct payments, tax expenditures or through the provision of free seedlings and direct assistance to the landowner. Governments also will have to bear various other afforestation program costs, including the cost of marketing, educational material, technical support, measurement and monitoring of afforestation and carbon sequestration performance, verification of sequestration performance for giving carbon credits, and administration of incentive mechanisms. At the same time, there are also important spin-off benefits from afforestation that should be of interest to governments, such as potential contributions to rural diversification and employment.

While government could pay for afforestation in its entirety, the Forest Sector and Sinks Tables believe that afforestation efforts need not be funded solely by government. This is because afforestation has at least three benefits (other than helping to meet Canada's Kyoto commitment, a key interest for governments) that could be of interest to landowners or to other participants.

1 Although landowners will be changing the current use of their land when they afforest it, the wood may be a source of future revenue when and if it is used for forest products or bioenergy. The current value of the future harvest will depend on the species grown, how long in the future the harvest occurs and future prices. Current interest in afforestation for forest products or bioenergy is limited due to relatively inexpensive alternatives (timber from public lands, low cost fossil fuels) and afforestation for these purposes likely will require fast-growing species on sites with good productivity for growing trees (though the sites may be of lower productivity for agricultural purposes). This will increase initial costs but also result in an earlier return on the afforestation investment. As already discussed, though, the future harvesting of afforested areas raises important issues about accounting for the loss of carbon that still need to be resolved in international negotiations.

We did not include estimates of future revenues for forest products or bioenergy in calculating the cost of the afforestation actions. In most cases, including these revenues will not reduce the estimated present value of the costs significantly. This is because the discounted future value of the afforested areas for forest products or bioenergy reflects two offsetting effects. As the trees grow their commercial value (eg. for forest products) increases but this is largely offset by the effect of discounting to obtain the present value in 2000. The value of the trees for commercial purposes can be proxied by applying current regional stumpage rates (payments made to provincial governments for timber harvested on public land) to the standing merchantable tree volume at any given point in time. Applying these rates to the proposed afforestation actions involving traditional trees species (ie. a total area of 793,000 ha excluding the fast-growing plantation action) results in a commercial present value of 1997$3 million for the areas afforested by 2010, using a 10% discount rate. If a 6% discount rate is used, which is a common approach to valuing timberland, the present value is about 1997$4 million. While the tree volume will be substantially larger in 2030, the effect of the discounting is such that its present value will have increased to only 1997$4 to $12 million depending upon the discount rate. Accounting for this value has only a marginal impact on the net cost of afforestation using traditional slower growing species.

Figure 4.3: Examples of afforestation activities and uses



However, accounting for the value of the afforested area for forest products or bioenergy has a larger impact when fast-growing species are used since tree growth rates are much faster and harvesting occurs much sooner. We provide a sensitivity analysis on this subject in the discussion of the fast-growing plantation action.

2 The carbon itself will have a value that will reflect the future demand for and supply of carbon credits, which in turn will be a function of the cost of alternative emission reducing and carbon sequestration possibilities available domestically and internationally. Whether landowners can obtain this value will depend on the systems created for domestic carbon trading. They may also need to bear costs associated with obtaining value from the carbon because of the need to measure sequestration if the carbon is to be bought and sold. And again, the possibility of responsibility for debits associated with the afforestation must be considered, whether through loss of carbon from natural causes, harvesting, or deforestation. **We did not account for the value of credits obtained for sequestration or emission reductions in any of the actions analysis.**

3 Afforestation will have many other benefits to landowners or others related to forest restoration, habitat enhancement, soil conservation, water quality, aesthetics, protection from wind and the sun, and other environmental non-monetary benefits. Some owners may be willing to absorb some of the planting, maintenance, protection and opportunity costs themselves because of the value they place on these benefits. For example, if a landowner places a high value on increased biodiversity that might result from afforestation, he or she could require less incentive to afforest than another owner who was solely interested in financial returns. **We did not quantify these non-financial benefits.**

Incentives likely will be needed to encourage the involvement of many participants interested in these benefits, but the Forest Sector and Sinks Tables believe that the mobilization of other participants could be the most cost effective way to achieve afforestation targets.

As well as those interested in environmental benefits, carbon or harvesting, there could also be scope to involve potentially large areas which undergo regular vegetation management (for example, cutting grass) and for which planting trees could be an alternative. These include electric utility transmission corridors, highway corridors, municipal land-fill areas that have reached their capacity, areas in commercial and industrial parks, and areas around de-commissioned mines and quarries. Planting trees may be a cost-effective alternative to periodic vegetation management in some of these areas, especially if the value of the additional carbon can be obtained.

Creating a market for carbon in which trading of carbon from afforestation is included will have large impact on the economics of afforestation, as it might for energy and efficiency actions. A carbon market could create proponents who are willing to invest in afforestation in expectation of using or selling the carbon. The greater the value of carbon, the less the incentive that will have to be provided for afforestation, provided that landowners or other investors in afforestation can obtain the carbon value. However, monitoring and verification systems required for afforestation are likely to be more detailed and costly when the carbon can be traded, especially if the measurement, monitoring and verification must be done for each individual afforested area.

Potential Market Opportunities for Afforestation

Establishment of plantation forests for commercial purposes has not been of major interest to the Canadian forest industry given the large and extensive area of forests available for timber production and the historically low cost of timber resources from those forests. In the future however, there may be increasing interest in and opportunities for commercial investment in afforestation projects for carbon sequestration and other benefits such as increased timber and fibre supply. Changing public policies and regulations relating to the sustainable management of Canada's forests, such as the use of codes of forest practice and declaration of protected reserves and parks consistent with international and domestic agreements, for example, may result in some restrictions in the future availability of timber resources. Key structural changes in global pulp and paper markets have also result in increased pressure to reduce costs to maintain international competitiveness, including wood procurement costs. Recent changes such as the emergence of low cost suppliers of fibre and pulp mainly from the southern hemisphere, as well as rising domestic wood costs, have resulted in the Canadian industry repositioning itself to ensure its long term international competitiveness. Several strategies are being implemented such as efforts to increase pulp yields, integration of sawmills to secure access to available wood chips and residues, and the establishment of plantation sources in areas experiencing local wood supply shortages.

Afforestation may consequently play an increasing role in the future of the Canadian forest industry as an additional resource, but existing barriers to supply such as the large number and scattered distribution of private lands and landowners would need to be overcome. The predominance of private woodlots as a source of timber supply in the Maritimes region provides an example of the type of co-operative supply arrangements which could provide a model for forest industry involvement in large scale afforestation.

As discussed in the previous section, the future development of international and domestic policies relating to carbon trading and the treatment of forests (i.e. what happens after harvest) under the Kyoto Protocol is likely to have an important bearing on opportunities to encourage landowners to participate in afforestation programs. Depending on the structure of trading rights and the value of carbon when traded, and on other issues such as the possible inclusion of forest products when accounting for carbon credits, there are likely to exist a range of commercial opportunities for public and private sector partnerships with landowners to increase afforestation in Canada.

The Kyoto Protocol and IPCC ghg emission inventory guidelines do not presently account for carbon stored in long-lived forest products, but several alternative methods are presently under consideration. These alternative methods take into account product groups, product life times and trade implications in varying ways. A direct implication of accounting for forest products as a long term store of carbon may be to increase the financial attractiveness of afforestation projects where those projects are intended to be harvested on a sustainable basis. This is because investors and landowners may receive carbon credits under a future trading system for the net impact of carbon sequestration in planted forests and associated forest products that would be converted from the available biomass. The level of potential benefits would depend on the types of forest products and carbon retention cycles involved and the outcome of future negotiations on the treatment of forest products, which is still highly uncertain (see section 4.5.4).

In particular, forest sector and energy companies may pursue joint venture arrangements with landowners once carbon trading rules become developed, as the former generally have greater access to the necessary capital and expertise, are better able to manage the risks associated with afforestation, and could have strong commercial motivations (e.g. source of fibre, ghg cost reduction) to pursue partnerships with landowners. The benefits of such arrangements may be significant for individual landowners in terms of sharing the risks and costs of afforestation projects with the companies and organizations (e.g. investment brokers) involved. A disincentive to some landowners of long rotations and investment cycles from afforestation projects may also be partly overcome through the use of annuity or profit-sharing arrangements with joint venturers. This would provide more cash flow flexibility from the utilization of the biomass material. From an overall program perspective, the encouragement of private sector partnerships based on viable commercial opportunities is likely to be one effective way of mobilizing interest from some rural landowners and increasing the likelihood of a longer term commitment and replanting of afforested areas.

However, interest in joint private sector afforestation projects will be balanced against other ghg cost reduction options available to those companies or agencies involved, such as more intensive management of existing forests or investment in global forest sector projects. The future development of Kyoto mechanisms such as Joint Implementation (JI) and the Clean Development Mechanism (CDM) may provide additional opportunities for reducing the costs of meeting ghg reductions, through for example, investment in fast-growing plantations as 'carbon offset' projects in many tropical and temperate regions of the southern hemisphere and the United States, where faster tree growing rates would tend to provide a better return on investment than might typically be available in Canada.

There are likely to be important opportunities to target available lands for growing trees specifically for joint carbon sequestration and other commercial benefits, including industrial fibre, solid wood products and bioenergy uses. Over the past few decades the Canadian forest products industry has undertaken some afforestation projects as a means of augmenting fibre supply at a local level. Approximately 2,400 ha has been planted in Eastern Ontario and 3,600 ha in southern BC. The establishment of spruce plantations for fibre supply on privately purchased lands has also been undertaken on a periodic basis in New Brunswick. In comparison, in the US Pacific Northwest, about 27,000 ha have been planted. Currently, the strongest interest in planting hybrid poplar in Canada is in Alberta where planting of at least 20,000 ha for pulp fibre is forecast in the north western part of the province.

In each case favourable economic factors presumably acted as an incentive - these include the close proximity of the land to a mill or market, the productive capacity of the land and relatively low cost of the land. These factors may not apply in the context of a widespread afforestation program. At an operational level, the potential advantages of plantations for forest products companies include a source of fibre with easier accessibility and lower transport costs if established close to a mill, and a uniform resource that can be intensively managed for higher growth rates and for specific uses. From a regional perspective however, the economic viability and potential for increased forest industry involvement in afforestation projects will in large part depend upon three important factors. These factors include:

- a regional wood deficit or forecast shortage;
- an available pool of technical (e.g. nursery and plantation management) expertise; and
- a large base of suitable land.

A preliminary assessment suggests that at least two of the three conditions exist in most parts of the country, but all three factors are only present in some parts of Ontario and Quebec and in northern Alberta. This suggests the necessary pre-conditions for significant forest industry involvement in afforestation currently exists only in these areas.

Economics of Plantations for Bioenergy and Forest Products

While an internationally accepted method for carbon stock accounting has yet to be finalized, current reporting guidelines of the IPCC treat the harvesting of forests for bioenergy as a non-emission source for national GHG inventories. There may be scope for afforestation projects for bioenergy that could provide short-term carbon sequestration benefits as well as substitution of traditional fossil fuels with renewable bioenergy.

Since 1978 the federally supported Energy from the Forest (ENFOR) Program has been involved in facilitating research and development into biomass energy. Based on ENFOR and other studies, hybrid poplar and willow have been identified as two important species having potential for forest energy plantations. Poplars can be typically grown over short rotations of 12 to 15 years, while willows can be periodically harvested every 3-5 years over a 20 year rotation. However, as a renewable energy source, willow appears to be uncompetitive in many current applications except in eastern Canada where fossil fuel prices are generally higher than for other regions. Current impediments to the commercialization of short rotation willow as an energy crop include low cost forest and agricultural crop residues such as sawmill residues and the lower cost of perennial grass feedstocks such as switchgrass. Furthermore, biomass energy plantations are least preferred on a cost basis for liquid fuel and electricity production applications in large scale industrial plants. This situation could change if conventional energy prices were to increase over the longer term or the potential carbon sequestration benefits of renewable bioenergy were recognized in any future carbon trading system. In particular, the direct heat application of wood chip heating and pellets from willow plantations offers promising commercial opportunities for remote rural communities.

For example, previous research has suggested that utilization of forest biomass for domestic heating may have good economic potential in remote First Nation communities which warrants further analysis and field testing.

Poplar plantations, on the other hand, tend to have a competitive advantage as a source of industrial fibre rather than for bioenergy given current energy prices, and they have been extensively planted for this purpose in the Pacific Northwest and North-Central regions of the United States. Poplars can be used for a variety of products including pulp and paper, oriented strand board (OSB), particle board, some solid wood products, and engineered lumber. Poplar fibre is mainly used in the production of pulp and paper and OSB, but offers potential in the rapidly evolving engineered lumber industry. Current industry procurement costs are approximately $100 per tonne (about $9.7 per m^3, after logging and transportation costs have been deducted), which is considerably higher than for bioenergy market values. While short rotation poplars used for production of pulp and paper and OSB appears viable even in the absence of potential carbon trading benefits, the costs of growing the fibre for other commercial uses is almost double its current potential market value.

Potential Policies to Encourage Afforestation

Table 4.2.5 summarizes a variety of possible policies and mechanisms that could be part of an afforestation program or programs to encourage block plantations and shelterbelts.

Table 4.2.5
Impediments and Possible Policies for Block Plantation and Shelterbelt Afforestation

Impediments to Implementation	Potential Policies As Part of Afforestation Program(s)
1 **Lack of knowledge about afforestation, site selection, species selection, and concern about impacts on land**	**1.1 Technical assistance and information at no cost** Responsibility: Federal government, provincial governments, probably through existing mechanisms such as PFRA in Prairies; wood lot owner associations, forestry associations Timeframe: Initiate in 2000,as part of afforestation program(s) Cost: Unknown **1.2 Program to market afforestation** Responsibility: Federal government, provincial governments, wood lot owner associations, forestry associations Timeframe: Initiate in 2000,as part of afforestation program(s) Cost: Unknown **1.3 Encourage/sponsor development of landowner afforestation associations as a source of information and assistance** Responsibility: Federal government, provincial governments Timeframe: Initiate in 2000, as part of afforestation program(s) Cost: Unknown
2 **Loss of landowner revenue from existing land use**	**2.1 One-time per hectare payment, 50% paid upon planting and commitment to afforestation for a specified period, with the remainder paid upon successful establishment ('free-to-grow' stage).** Maximum payment could be proxied by appraised or market land values. Commitment period depends in part on species Responsibility: Federal and provincial governments, through existing mechanisms where possible; companies, municipalities or others with an interest in securing carbon or fibre; joint funding arrangements with governments could be made as a way of attracting greater involvement of companies Timeframe: Initiate in 2000, as part of afforestation program(s) Cost: Depends on location and previous use of land, as well as the duration of the commitment of the landowner; may range from $0 / ha to $1,000 / ha **2.2 Annual land rental payments upon commencement of afforestation activity, with a commitment to afforestation for a specified period**. Commitment period depends in part on species Responsibility: Federal and provincial governments, through existing mechanisms where possible; companies, municipalities or others with an interest in securing carbon or fibre; joint funding arrangements with governments could be made as a way of attracting greater involvement of companies Timeframe: Initiate in 2000, as part of afforestation program(s) Cost: Depends on location and previous use of land; may range from $0/ha to $100/ha per year **2.3 One-time per hectare payment to add a conservation easement to the deed for the land.** The easement would create a requirement to maintain forest cover and/or create a restriction on certain activities such as harvesting or deforestation. The easement would be permanent in that it would not change with change in ownership. Responsibility: Federal and provincial governments Timeframe: Initiate in 2000 Cost: Depends on location and previous use of land; may range from $100/ha to $3,000/ha **2.4 Make funds received for afforestation partially tax deductible through tax credits.** Responsibility: Federal and provincial governments Timeframe: Initiate in 2000 Cost: Unknown tax expenditure **2.5 Establish market for carbon credits which includes carbon from afforestation, in which landowners, other investors in afforestation, and those interested in using afforestation carbon credits, can trade** Responsibility: Federal and provincial governments Timeframe: As soon as possible Cost: Unknown

Impediments to Implementation	Potential Policies As Part of Afforestation Program(s)
3 **Costs to landowner or others who undertake the planting and maintenance**	**3.1 Full or partial (50-75%) compensation to landowners, who bear all annual costs related to establishment and maintenance, up to a specified maximum payment per year per farm.** Responsibility: Federal and provincial governments, through existing mechanisms where possible; companies, municipalities or others with an interest in securing carbon or fibre; joint funding arrangements with governments could be made as a way of attracting involvement of companies Timeframe: Initiate in 2000, as part of afforestation program(s) Cost: Will depend on a variety of factors including location, type of afforestation, species; may range from $500 / ha to $3,500 / ha , spread over several years, for full compensation **3.2 Seedlings at low cost (10-25%) or no cost** Responsibility: Federal and provincial governments, through existing mechanisms where possible; companies, municipalities or others with an interest in securing carbon or fibre; joint funding arrangements with governments could be made as a way of attracting involvement of companies Timeframe: Initiate in 2000, as part of afforestation program(s) Cost: Will depend on species used and availability - typical seedling cost is $200-400 / ha **3.3 Labour provided, or costs paid fully or partially** Responsibility: Federal and provincial governments, through existing mechanisms where possible including employment programs; companies, municipalities or others with an interest in securing carbon or fibre; joint funding arrangements with governments could be made as a way of attracting involvement of companies Timeframe: Initiate in 2000, as part of afforestation program(s) Cost: Will depend on labour rates and characteristics of the site preparation, planting and maintenance - may be $500-2,500 / ha **3.4 Change taxation regulations to make non-funded afforestation expenses deductible in the year in which they occur, or otherwise treat planting trees as a (long-term) agricultural crop** Responsibility: Federal and provincial governments Timeframe: Initiate in 2000 Cost: Unknown tax expenditure **3.5 Make funds received for afforestation partially tax deductible through tax credits.** Responsibility: Federal and provincial governments Timeframe: Initiate in 2000 Cost: Unknown tax expenditure **3.6 Change property tax systems to make taxes on afforested land similar to those for agricultural land** Responsibility: Municipal and provincial governments Timeframe: Initiate in 2000 Cost: Unknown tax expenditure
4 **Shortage of seedling stock of species required for afforestation**	**4.1 Provide grants or low-interest loans for investments in nursery capacity** Responsibility: Federal and provincial governments Timeframe: Initiate in 2000, as part of afforestation program(s) Cost: Unknown
5 **Uncertainty about sequestration potential and measurement, monitoring and verification**	**5.1 Additional incentives to early landowner participants who act as pilot projects to help confirm growth and yield, especially of young trees** Responsibility: Federal and provincial governments Timeframe: Initiate in 2000, as part of afforestation program(s) Cost: Unknown **5.2 Additional incentives to early landowner participants who act as pilot projects to help develop sequestration measurement, monitoring and verification protocols** Responsibility: Federal and provincial governments Timeframe: Initiate in 2000, as part of afforestation program(s) Cost: Unknown **5.3 Minimum carbon sequestration guarantees for early afforestation projects to landowners and others who invest because of the potential value of carbon** Responsibility: Federal and provincial governments Timeframe: Initiate in 2000, as part of afforestation program(s) Cost: Unknown

4.2.3 Action: Plantations of Fast-Growing Species

ACTION:	***Plant 50,000 hectares of private land across Canada over 5 years (2001 to 2005), using fast-growing tree species***

The action assumes that 50,000 ha of privately-owned land could be planted across Canada using fast-growing tree species, at a rate of 10,000 ha per year from 2001 to 2005. The analysis is based on planting hybrid poplar but other species could be used, such as willow. Hybrid poplar stands will begin to break-up naturally by about age 30 and decay rapidly. There is little data on the collapse of poplar stands but it is likely that by age 50 a stand will be almost completely broken up and that poplar tree biomass carbon will be minimal.

As well as sequestering carbon the trees could have other end uses. One possible end use is as a nurse crop. In some parts of the country, such as southern Ontario, planting hybrid poplars on un-used agricultural land would provide the conditions needed to encourage a transition to native hardwood forests which would sequester carbon over a much longer period than would the hybrid poplars. The forest products and energy industries could be very interested in planting and harvesting fast-growing plantations for use in forest products, such as pulp and oriented strand board, or for bioenergy.

There is a growing commercial interest in hybrid poplar plantations on the part of the forest products industry in Canada and the United States as discussed in the previous section. Typical harvesting ages are 12-15 years in Canada. This would mean that areas planted in 2001 will be harvested in 2012 to 2015. Thus harvesting will begin either at the end of the first commitment period or immediately afterward. This raises the issue of the time path of carbon credits and potential debits. The potential for carbon debits is related to how harvesting of afforested areas and the storage of carbon in forest products are treated in the Kyoto Protocol. The issues were discussed above, where it was noted that there are varying views on these questions. If harvesting does not count as a debit then no issues arise. On the other hand, if the Protocol does require accounting for debits from harvesting afforested areas then the time path of the credits and debits becomes important.

We assume that, if a plantation is harvested, it will be as part of a continual cycle of planting and harvesting for industrial purposes and that the long term effect would be an increased carbon reservoir, especially if some of the carbon is stored in forest products. However, the net annual sequestration will vary over time as will the net credit that Canada can count. If this continual cycle does not occur (i.e., areas are not regenerated back to forest), then there would be a deforestation debit, reflecting the permanent conversion of the forest area back to another land-use.

Table 4.2.6
Action Costs and GHG Impacts of Fast-Growing Plantations

	Estimate	Assumptions
Planting program		
planting period	5 years	program starts in 2000, with planting beginning in 2001
area planted per year	10,000 ha / yr	no ramp-up in activity: planting starts immediately at 10,000 ha / yr
total planting	50,000 ha	
Incremental CO_2 sequestration		includes above and below-ground tree biomass only; emissions from fossil fuels used in planting are included in the estimates; net carbon sequestration on the land prior to the planting assumed to be zero; uses hybrid poplar growth curves
2010	1.31 Mt CO_2	
2000-2050, average annual	see note	
Costs		
Average planting cost (1997$)	$3,395 / ha	includes cost of site preparation, seedlings, follow-up care and labour
Average annual opportunity cost (1997$)	$ 25 / ha / yr	
Cost calculations		
NPV of planting costs (1997$)	$130.8 million	uses a 10% discount rate
NPV of opportunity cost (1997$)	$10.4 million	uses a 10% discount rate, and based on payments for 25 years
Cost effectiveness (1997$ / tonne)		
2008-12	$22.2 / t CO_2	using total non-discounted carbon sequestration 2008-12

Note: we assume that harvesting occurs at age 13-15 years and the area is replanted. Over the 2000-50 period, the net carbon sequestration will depend either on the transition to a natural forest or on how harvesting of afforested areas and carbon in the resulting forest or fuel products are counted in the Protocol.

The key point is that if fast-growing species are planted there is a possibility that Canada will have to accept debits that will offset some of the credits as early as the first commitment period, because of the fast growth and relatively short lives of the trees. Of course, these same issues arise for all of the other plantation actions, but not for many decades in the future. For simplicity, in our analysis we assumed that no harvesting will occur in the first commitment period (harvesting occurs at age 13-15) so that the sequestration in the period is unambiguous and there is no possibility of a debit associated with harvesting. Earlier harvesting could reduce the net sequestration in the first commitment period. Over the 2000-50 period, the net carbon sequestration will depend either how the transition to a natural forest occurs or on how harvesting of afforested areas and carbon in the resulting forest products are treated in the Protocol.

If we assume that harvesting and carbon in forest products are not counted, as is currently the case in the Protocol, then any further carbon credits will depend on how afforestation and reforestation are defined. If they are defined using the IPCC definitions, then replanting of the harvested area will yield no further credit (but failure to replant will be deforestation and will yield a debit). In this case, the net effect will be the one-time credit equal to the initial afforestation.

Table 4.2.7
Regional Implications of Fast-Growing Plantations

Province	Land Planted ha	Mt CO_2 Sequestered 2010	NPV Planting and Opportunity Cost 1997$ mill	Cost Effectiveness 1997$ / t CO_2 2008-12
BC	5,000	0.16	14.1	18.1
Prairies	27,500	0.69	77.7	23.2
Ontario	7,500	0.20	21.2	21.8
Quebec	7,500	0.20	21.2	21.8
Atlantic	2,500	0.06	7.1	26.2
Canada	50,000	1.31	141.2	22.2

Regional areas for planting were chosen based on a rough assessment of the likely land availability and the current level of interest, which is highest in Alberta. Differences in sequestration and cost effectiveness across regions reflect assumptions about differences in growth curves. In general the highest productivity is in southern BC, with medium productivity in Eastern Canada and central BC, and lower productivity in the Prairies.

When planting and opportunity costs are accounted for, the sequestration of 1.3 Mt CO_2 in 2010 has a cost effectiveness of 1997$22.2 / t CO_2 in 2008-12. If the plantations are harvested then the revenue from the use of the wood in forest products or bioenergy will partially offset these costs. If we assume that the trees are harvested at age 13 then three harvests are possible by 2050. Using a 10% discount rate results in a present value in 2000 for the harvests of 1997$14-27 million, where the lower figure is based on an estimated current bioenergy market price of 1997$4.6 / m^3 of wood (net of logging and transportation costs) and the higher figure is based on an estimated forest products market price of 1997$9.7 / m^3. Accounting for this revenue improves the cost effectiveness of the action from $22 / t CO_2 to $18-20 / t CO_2, but note that the possibility of carbon debits has not been accounted for.

4.2.4 Action: Shelterbelt Planting in the Prairie Provinces

ACTION:	***Plant shelterbelts on private land in the Prairies provinces each year from 2001 to 2015 (15 years), with a target planting rate of 13,000 ha per year***

The action assumes that, as a first approximation, about 169,000 ha of privately-owned land could be planted in shelterbelts over a 15 year period in the Prairie region. The annual target planting would be 13,000 ha per year with a ramp-up to the full target level between 2001 and 2005. This action builds on existing interest in and programs to promote shelterbelts, which have been planted in the Prairie provinces for many decades for the purposes of soil conservation and farmyard windbreaks, with much of the planting supported by the Prairie Farm Rehabilitation

Administration (PFRA). At present at least 20,000 farms in the region have shelterbelts, averaging under 1.5 ha per farm. This action assumes that wide shelterbelts (4 rows of trees) will be planted rather than the usual 1-2 rows, but a broader action could promote all types of shelterbelt planting (single row, multi-row, riparian, etc.). One advantage of shelterbelts is that they can be established as perimeter plantations without giving up entire fields, as would be the case with block plantations. A focus on shelterbelts therefore may increase the attractiveness of planting trees. However, shelterbelts could also have additional costs in the form of fencing to protect growing trees from livestock.

We assume shelterbelts will be planted in areas with soil productivity that is rated poor or medium for agricultural purposes, mainly in the southern half of the region, as these areas could benefit most from shelterbelts which reduce soil erosion and increase crop yields. Planting could be done in other areas as well. While soil productivity is not high, the areas planted will divert some land from crops and grazing, so that the land accessed likely will be more valuable than average marginal agricultural land. The action also assumes that incentives can be provided such that roughly 17% of farms in the Prairies will participate in shelterbelt planting of about 10 ha per farm - this is considered a very ambitious but achievable goal. If only 5 ha are planted per farm then about 35% of all farms would have to participate, a substantial participation rate.

Species used in shelterbelts, and their shares in planting, will likely be chosen based on past success in shelterbelts and on species most likely to be available in existing nursery facilities. The analysis for this action assumed that future use of the wood was not a primary factor in determining species. Faster-growing species could be encouraged to maximize CO_2 in the initial commitment period, while other species would be more appropriate for sequestering in the long term.

Table 4.2.8
Action Costs and GHG Impacts of Prairie Shelterbelts

	Estimate	Assumptions
Planting program		
planting period	15 years	program starts in 2000, with planting beginning in 2001;
annual planting target	13,000 ha / yr	5-yr ramp-up to annual planting target by 2005
total planting	169,000 ha	
Incremental CO_2 sequestration		includes both above and below-ground biomass;
2010	0.15 Mt CO_2	emissions from fossil fuels used in planting are included in the estimates;
2000-2050, average annual	0.58 Mt CO_2 / yr	soil carbon sequestration is not included; net carbon sequestration prior to the shelterbelts is assumed to be zero
Costs		
Average planting cost (1997$)	$1,290 / ha	includes cost of site preparation, seedlings, follow-up care and labour
Average annual opportunity cost (1997$)	$10 / ha / yr	
Cost calculations		
NPV of planting costs (1997$)	$ 98.7 million	uses a 10% discount rate
NPV of opportunity costs (1997$)	$ 8.5 million	uses a 10% discount rate; annual payments made for 25 years
Cost effectiveness (1997$ / tonne)		
2008-12	$ 140.7 / t CO_2	using total non-discounted carbon sequestration 2008-12
2000-50	$ 3.7 / t CO_2	using total non-discounted carbon sequestration 2000-50

Table 4.2.9
Regional Implications of Prairie Shelterbelts

Province	Target Planting ha / yr	Mt CO_2 Sequestered 2010	Mt CO_2 Sequestered per year 2000-50	NPV of Planting and Opportunity Costs 1997$ mill	Cost Effectiveness	
					1997$ / t CO_2 2008-12	1997$ / t CO_2 2000-50
Alberta	6,600	0.08	0.30	54.5	135.7	3.6
Sask.	5,150	0.06	0.22	42.4	148.6	3.8
Manitoba	1,250	0.01	0.06	10.3	137.6	3.6
Prairies	13,000	0.15	0.58	107.2	140.7	3.7

Note that the level of sequestration in the first commitment period is highly dependent on the species chosen and on the assumption regarding planting schedule - for example, a delay in planting to 2005 reduces sequestration in 2010 from 0.15 Mt CO_2 to 0.05 Mt CO_2. Irrespective of when planting starts, carbon sequestration will continue to occur after 2050, depending on the species used, so that the cost per tonne of CO_2 sequestered when considered over a longer period than 2000-50 would be lower than shown in the above Table.

Planting costs for shelterbelts will vary widely from site to site and are uncertain because, to date, shelterbelt planting programs have relied to a large degree on volunteer labour and free plants. Opportunity costs are very uncertain. We have assumed an opportunity cost of $10/ha/yr, well below the average annual rental value of farmland in the Prairie provinces, which is about $100-120/ha/yr. Shelterbelts would most likely be done on land with below-average value for agricultural purposes but using a figure of $100/ha/yr rather than $10/ha/yr shows the sensitivity of our results to the opportunity cost assumption. Using the higher figure raising the cost per tonne to $210 / t CO_2 in the first commitment period and $5.5 / t CO_2 over 2000-50. The regional differences reflect differences in the land area considered to be available, the distribution of species planted and the areas of medium and poor soil productivity land that are planted.

4.2.5 Action: Block Plantations in the Prairie Provinces

ACTION:	***Plant block plantations on private land in the Prairies provinces each year from 2001 to 2015 (15 years), with a target planting rate of 20,000 ha per year***

This action assumes that, as a first approximation, about 260,000 ha of privately-owned land could be planted in block plantations over a 15 year period in the Prairie region. The annual target planting would be 20,000 ha per year, with a ramp-up to the full annual planting target by 2005. This action requires that landowners commit to removing blocks of their farm land from their current agricultural uses, if any, and convert them to tree plantations. Block plantations would vary in size depending on individual farm size and landowner interest.

Table 4.2.10
Action Costs and GHG Impacts of Prairie Block Plantations

	Estimate	Assumptions
Planting program		
planting period	15 years	program starts in 2000, with planting beginning in 2001;
annual planting target	20,000 ha / yr	5-yr ramp-up to annual planting target by 2005
total planting	260,000 ha	
Incremental CO_2 sequestration		includes both above and below-ground biomass;
2010	0.37 Mt CO_2	emissions from fossil fuels used in planting are included in the
2000-2050, average annual	1.43 Mt CO_2 / yr	estimates; soil carbon sequestration is not included; net carbon sequestration prior to the plantations is assumed to be modest and is subtracted from the sequestration due to the action
Costs		
Average planting cost (1997$)	$ 1,650 / ha	includes cost of site preparation, seedlings, follow-up care and labour
Average annual opportunity cost (1997$)	$ 10 / ha / yr	
Cost calculations		
NPV of planting costs (1997$)	$ 201.1 million	uses a 10% discount rate
NPV of opportunity costs (1997$)	$ 13.1 million	uses a 10% discount rate, with payments made for 25 years
Cost effectiveness 1997$ / tonne		
2008-12	$ 114.6 / t CO_2	using total non-discounted carbon sequestration 2008-12
2000-50	$ 3.0 / t CO_2	using total non-discounted carbon sequestration 2000-50

We assume that efforts to promote block plantations will be targeted to areas with soil productivity that is relatively good for growing trees, mainly in the southern half of the region. While soil productivity is fairly good for trees, the areas planted may not always require diversions of land from crops and grazing because planting marginal agricultural land (that is, land not used or with little suitability for agricultural uses) will be the main objective. Tree species used in block plantations, and their shares in planting, will be determined based on expectations as to the best possible uses of the plantation in the future, whether for environmental purposes (forest restoration, habitat etc.), forest products or energy. The analysis for this action did not take this into account explicitly.

Note that the level of sequestration in the first commitment period is highly dependent on the species chosen and on the planting schedule - for example, a delay in planting to 2005 reduces sequestration in 2010 from 0.37 Mt CO_2 to 0.14 Mt CO_2. Irrespective of when planting starts, carbon sequestration would continue to occur after 2050, depending on the species used, so that the cost per tonne of CO_2 sequestered when considered over a longer period than 2000-50 would be lower than shown in the above Table.

Opportunity costs are a major area of uncertainty. We have assumed an opportunity cost of $10/ha/yr, well below the average annual rental value of farmland in the Prairie provinces, which is about $100-120/ha/yr. Block plantations would most likely be done on land with below-average value for agricultural purposes but using a figure of $100/ha/yr rather than $10/ha/yr shows the sensitivity of our results to the opportunity cost assumption. Using the higher figure raising the cost per tonne to $177 / t CO_2 in the first commitment period and $4.6 / t CO_2 over 2000-50.

Table 4.2.11
Regional Implications of Prairie Block Plantations

Province	Planting Target ha / yr	Mt CO_2 Sequestered 2010	Mt CO_2 Sequestered per year 2000-50	NPV of Planting and Opportunity Costs 1997$ mill	Cost Effectiveness	
					1997$ / t CO_2 2008-12	1997$ / t CO_2 2000-50
Alberta	8,700	0.16	0.62	93.4	114.6	3.0
Sask.	7,650	0.14	0.55	82.0	114.6	3.0
Manitoba	3,650	0.07	0.26	38.8	114.6	3.0
Prairies	20,000	0.37	1.43	214.2	114.6	3.0

Cost effectiveness does not vary by province as the same quality of land and mix of species is assumed to be used in each province for this action.

4.2.6 Action: Block Plantations in British Columbia

ACTION:	***Plant block plantations on private land in British Columbia each year from 2001 to 2015 (15 years), with a target planting rate of 13,000 ha per year***

The action assumes that, as a first approximation, about 169,000 ha of privately-owned land could be planted in shelterbelts over a 15 year period in BC. The annual target planting would be 13,000 ha per year with a ramp-up to the annual planting target by 2005. The focus of this action is privately owned agricultural land that is considered under-utilized, un-used or marginal. While block plantations are the focus of this action, some of the planting could be in shelterbelts. Thus this action generally requires that landowners commit to removing blocks of their farm land from their current agricultural uses, if any, and convert them to tree plantations. Block plantations would vary in size depending on individual farm size, land quality/productivity and landowner interest. In calculating the carbon sequestration we used species commonly used in reforestation in Canada. In practice, the actual species chosen will reflect decisions as to the preferred uses, including for carbon, other environmental benefits, forest products or energy.

Table 4.2.12
Action Costs and GHG Impacts of British Columbia Block Plantations

	Estimate	Assumptions
Planting program		
planting period	15 years	program starts in 2000, with planting beginning in 2001;
annual planting target	13,000 ha / yr	5-yr ramp-up to annual planting target by 2005
total planting	169,000 ha	
Incremental CO_2 sequestration		includes both above and below-ground biomass; emissions from fossil fuels used in planting are included in the estimates; soil carbon sequestration is not included; net carbon sequestration prior to the plantations is not accounted for
2010	0.04 Mt CO_2	
2000-2050, average annual	0.70 Mt CO_2 / yr	
Costs		includes costs of site preparation, seedlings, follow-up care and labour
Average planting cost (1997$)	$1,027 / ha	
Average annual opportunity cost (1997$)	$10 / ha / yr	
Cost calculations		
NPV of planting costs (1997$)	$ 77.1 million	uses a 10% discount rate
NPV of opportunity costs (1997$)	$ 8.5 million	uses a 10% discount rate; payments made for 25 years
Cost effectiveness 1997$ / tonne		
2008-12	$ 452.5 / t CO_2	using total non-discounted carbon sequestration 2008-12
2000-50	$ 2.4 / t CO_2	using total non-discounted carbon sequestration 2000-50

Note that the level of sequestration in the first commitment period is highly dependent on the species chosen and on the planting schedule - for example, a delay in planting to 2005 reduces sequestration in the first commitment period by over 50%. Irrespective of when planting starts, carbon sequestration would continue to occur after 2050, depending on the species used, so that the cost per tonne of CO_2 sequestered when considered over a longer period than 2000-50 would be lower than shown in the above Table. Planting costs will vary widely from site to site and are uncertain.

The effect of differences in growth curves can be seen when the results for this action are compared to the results for the other afforestation actions. The curves uses for this action tended to show slower growth in the early decades after growth, but faster growth in later growth. In part this reflects real differences in growth rates in BC, especially on the Coast, compared to other parts of Canada. However, an unknown part of the difference is simply a reflection of lack of good knowledge about growth curves for plantations and for the first few decades of growth.

British Columbia is more varied physically and biologically than any other province in Canada and there are major differences across the province. This action assumes that these intra-provincial differences in suitability for and productivity of plantations are taken into account through species selection and the distribution of planting across the province. Most of the land planted is in the Interior where tree growth is slower (close to 90% of planted land), reflecting the availability of land. While only about 10% of the planted land is on the Coast, it accounts for 30% of the average annual carbon sequestration in the first commitment period, reflecting higher productivity.

4.2.7 Action: Block Plantations in Eastern Canada

ACTION:	***Plant block plantations in Eastern Canada each year from 2001 to 2015 (15 years) with a target planting rate of 15,000 ha per year***

This action assumes that, as a first approximation, about 195,000 ha of privately-owned land could be planted in block plantations over a 15 year period - 78,000 ha in Ontario, 78,000 ha in Quebec and 39,000 ha in the Atlantic provinces. The annual target planting would be 15,000 ha per year, with a ramp-up to the annual planting target by 2005. This action requires that landowners commit to removing blocks of their farm land from their current agricultural uses, if any, and convert them to tree plantations. Block plantations would vary in size depending on individual farm size and landowner interest. The 78,000 ha target for Ontario is about 50% higher than the land planted under the Ontario Woodlands Improvement Act which was in force for two decades from the mid 1960s to the mid 1980s. For the purpose of developing this option, specific tree species and their distribution were selected. Final species composition will be determined based on expectations as to the best possible uses of the plantation in the future, whether for environmental purposes, forest products or energy.

Note that the level of sequestration in the first commitment period is highly dependent on the species chosen and on the planting schedule - for example, a delay in planting to 2005 reduces sequestration in the first period by over 50%. Irrespective of when planting starts, carbon sequestration would continue to occur after 2050, depending on the species used, so that the cost per tonne of CO_2 sequestered when considered over a longer period than 2000-50 would be lower than shown in the above Table. Planting costs for will vary widely from site to site and are uncertain. Soil carbon represents about 7% of the total carbon sequestered during the first commitment period and about 15% over 2000-2050.

The estimates of sequestration are based on growth curves which reflect experience with plantations in Atlantic Canada. Thus these growth curves show faster growth than is usual for unmanged forests, at least in the early decades of tree life. Using different growth curves can result in substantially different results, especially in the first few decades after growth. For example, we explored the sensitivity of the results to using a set of lower growth curves based on non-plantation forests in Ontario. With these lower curves, sequestration in 2010 falls to 0.08 Mt CO_2 while sequestration over 2000-50 averages 1.70 Mt CO_2 per year. Accordingly, cost effectiveness in 2008-2012 was 1997$410 / t CO_2 and $1.9 / t CO_2 over 2000-50.

Table 4.2.13
Action Costs and GHG Impacts of Eastern Canadian Block Plantations

	Estimate	Assumptions
Planting program		
planting period	15 years	program starts in 2000, with planting beginning in 2001;
annual planting target	15,000 ha / yr	5-yr ramp-up to annual planting target by 2005
total planting:	195,000 ha	
Incremental CO_2 sequestration		includes both above and below-ground biomass and soil carbon; emissions from fossil fuels used in planting are excluded from the estimates; net carbon sequestration prior to the plantations is assumed to be zero
2010	0.22 Mt CO_2	
2000-2050, average annual	1.37 Mt CO_2 / yr	
Costs		includes cost of site preparation, seedlings, follow-up care and labour
average planting cost (1997$)	$ 1,500 / ha	
average annual opportunity cost (1997$)	$ 10 / ha / yr	
Cost calculations		
NPV of planting costs (1997$)	$ 147.2 million	uses a 10% discount rate
NPV of opportunity costs (1997$)	$ 9.8 million	uses a 10% discount rate; payments made for 25 years
Cost effectiveness 1997$ / tonne		
2008-12	$ 144.9 / t CO_2	using total non-discounted carbon sequestration 2008-12
2000-50	$ 2.3 / t CO_2	using total non-discounted carbon sequestration 2000-50

Given the great uncertainty about opportunity costs, we also assessed the impact of an annual opportunity cost of $50 / ha / yr. Using this opportunity cost results in a cost effectiveness for 2008-12 of 1997$181 / t CO_2, up from $145 / t CO_2 when the opportunity cost is $10 / ha / yr.

While the same species is used for each region, cost effectiveness varies across the regions because of differences in the distribution of the species in terms of areas planted. A breakdown of the estimates by provinces in Atlantic Canada was not done but most of the lands targeted are located in New Brunswick and Nova Scotia.

Table 4.2.14
Regional Implications of Eastern Block Plantations

Region	Planting Target ha / yr	Mt CO_2 Sequestered 2010	Mt CO_2 Sequestered per year, 2000-50	NPV of Planting and Opportunity Costs 1997$ mill	Cost Effectiveness	
					1997$ / t CO_2 2008-12	1997$ / t CO_2 2000-50
Ontario	6,000	0.11	0.56	62.8	120.0	2.2
Quebec	6,000	0.08	0.55	62.8	159.7	2.3
Atlantic	3,000	0.03	0.26	31.4	188.4	2.4
Eastern total	15,000	0.22	1.37	157.0	144.9	2.3

4.2.8 Further Assessment of Afforestation Actions

Competitiveness, Economic and Social Implications

- Sale of wood from block plantation actions will affect future timber supply. This may result in a reduction in future harvests on existing forested areas, or it could be used to develop new manufacturing facilities.
- Afforestation will present economic development, employment and diversification opportunities for rural communities in the form of tree planting and maintenance, and increases in nursery production. In the future, additional wood supplies for products or energy may also contribute.
- Nursery capacity for the production of the additional seedlings varies by region. Existing capacity is thought to be sufficient in BC. In the Prairie provinces existing capacity is considered sufficient to handle planting of roughly 33,000 ha/yr. This means that existing capacity is just sufficient for the proposed level of planting of the two Prairie actions combined. Overall, seedling supply is not likely to be a limiting factor given the 5 year ramp-up period.
- This action may have impacts on the agricultural sector if production of agricultural products are reduced, depending on the type of activity that occurred on the land diverted to shelterbelts or block plantations. The net effect on landowners, the agri-food industry and consumers will depend on the changes in prices paid for farmers' products, and polices in the agricultural sector. The net effects are expected to be minimal due the relatively low productivity and use of most of the agricultural lands planted.

Environmental and Health Impacts of Planting Actions

Positive Environmental Effects

The afforestation of marginal agricultural land can result in a range of environmental and land management benefits in addition to direct carbon sequestration benefits. These benefits include: improving overall soil and water quality; rehabilitating previously degraded lands; restoring degraded or fragmented forests; providing habitat for wildlife and increased biodiversity; providing rural diversification and aesthetic landscape benefits; and increasing the availability of renewable biofuels (as a substitute for fossil fuels and reduced CO_2 emissions) and long lived forest products (as a store of CO_2 and substitute for other energy intensive building products).

The afforestation of marginal agricultural land results in lower pesticide and chemical use and reduced leaching into groundwater and aquatic ecosystems compared to intensive agriculture. Afforestation can also reduce soil erosion and improve soil quality through increased stabilization of soils and regulation of water run-off, and it can rehabilitate lands degraded through previous land use practices. Research is continuing on the potential use of salt tolerant tree species to rehabilitate saline areas, which occur mostly in the Prairie Provinces.

Afforestation can contribute directly to promoting biodiversity and the provision of wildlife habitat through the replacement of land used for agricultural purposes with a more complex vegetation structure and forest ecosystem. The design and structure of afforestation planting can greatly influence the level of enhanced biodiversity benefits, and be complementary to other regional conservation objectives and adjacent ecosystems. Afforestation could also provide protection of headwaters, recharge areas and riparian areas. Protection of water quality and quantity will be especially important if climate change causes an increased incidence of drought in some parts of the country.

Increased afforestation will promote additional landscape, aesthetic and recreation benefits through an increase in forest cover and diversification of rural activities and opportunities. Afforestation based on agroforestry and shelterbelt systems can increase soil and cropland productivity, and provide additional agricultural benefits such as the provision of shade and shelter for livestock.

The environmental benefits of increased afforestation extend beyond the direct CO_2 sequestration of standing trees, and include the potential use of these trees as a renewable biomass fuel and substitute for fossil fuels. Offsetting the end use of fossil fuel reduces cumulative concentrations of air emission pollutants, including: carbon dioxide (CO_2) and nitrogen oxide (NO_X), along with smaller amounts of methane (CH_4), carbon monoxide (CO) and volatile organic compounds (VOC).

The harvesting and production of solid wood products from afforestation areas acts as a long term store of CO_2, and may be less environmentally damaging than other building materials and substitutes (e.g. concrete and steel) on a product life cycle basis. The life cycle benefits and costs of using forest products compared to other building products is an area of continuing research.

Adverse Environmental Effects

Afforestation programs will increase the use of pesticides and fertilizers when taking place on lands that were not previously in intensive use. As well, the overall soil and water quality improvements of an increase in afforestation may be partly offset in some cases by increased water and nutrient deficits where intensive short rotation species are used. These potentially adverse effects reflect the high water and nutrient demands of short rotation species, but can be mitigated through careful planning and use of sustainable planting practices (e.g. planting only on lands with the biophysical capability to support short rotation species). There is also some uncertainty on the net changes to soil carbon in the first few years following afforestation, although soil carbon increases over the life of the rotation.

Increased afforestation will result in higher standing biomass and the potential risk of increased fire and spread of forest diseases and pests compared to some pre-existing land uses. These potentially adverse effects can be mitigated through the use of fire protection measures and other planting controls designed to minimize the risk of pests and diseases, such as the use of appropriate tree species and pest control agents.

Non-forested areas can be quite complex and rich in terms of biodiversity and habitat (if not used intensively for agricultural purposes) and afforestation will replace this with new types and levels of biodiversity and habitat. Where plantations rely on one or a few species, especially if they are not indigenous to the location of the plantation, habitat diversity and biodiversity could be adversely affected.

Information Gaps

The overall soil and water quality changes resulting from afforestation on marginal agricultural land are generally well documented in the scientific literature, and quantified at a local level in many cases. Some key information gaps, or areas requiring further research, include: R&D on suitable salt tolerant tree species; soil and below ground carbon changes in the first few years following afforestation; potential off-site impacts of chemical and pesticide use in afforestation projects on aquatic and terrestrial ecosystems; the long term effect on water and nutrient budgets from increased afforestation (particularly for short rotation species); and the life-cycle benefits and costs of using forest products compared to other building products.

Summary

The afforestation of marginal agricultural land for carbon sequestration can result in important land management benefits, and in some cases adverse impacts, in addition to direct CO_2 sequestration benefits. The distribution of positive and negative impacts will be site specific. The benefits include improvements in overall soil and water quality; rehabilitation of previously degraded lands; providing habitat for wildlife and increased biodiversity; and increased rural diversification and aesthetic landscape benefits. Other CO_2 -related benefits include increasing the production of renewable biofuels (as a substitute for fossil fuels and reduced CO_2 and other emissions) and long-lived forest products as a store of CO_2. The positive and negative environmental effect will be more extensive in the Prairie provinces, where the largest share of the afforestation will occur.

Extent of Use of Planting Actions in Other Countries

- Other countries, such as the United States, are known to be exploring the potential for using domestic afforestation projects to help meet their Kyoto Protocol target. In countries such as New Zealand and Australia, new afforestation has occurred in the expectation of obtaining carbon credits. Domestic and foreign private companies have been involved in the efforts.
- A number of countries will benefit from carbon sequestration as a result of significant afforestation efforts (since 1990) that pre-date the Kyoto Protocol. Among these countries are New Zealand, Australia, Argentina, Ireland. Some countries provide significant direct government support for afforestation (Argentina, Ireland) while others have provided indirect support through regulatory changes which encourage investment in forest plantations (New Zealand). In each case, the motivation of the government has been primarily to increase development of the domestic forest industry rather than carbon sequestration.
- Some countries, such as the United States, have established afforestation programs designed to achieve conservation objectives on agricultural land and remove marginal agricultural land from production. In the United States, a variety of programs provide partial funding for tree planting for conservation purposes.

Further Analytical / Study Needs

- The analysis of the actions varied in terms of accounting for carbon. Soil carbon sequestration due to the Prairie and BC actions was not assessed. The analysis for this Prairie block action assumed that net annual carbon sequestration prior to block plantation planting was modest. This is assumed to be lost when plantations are developed, resulting in a slight reduction in net incremental carbon sequestered due to the action. The magnitude of this effect is very uncertain. For all of the other actions, the impact of afforestation on pre-existing levels of carbon sequestration were not estimated. Accounting for pre-afforestation carbon sequestration rates may raise or lower the net sequestration from the actions but there is inconclusive information on this topic, and it is also not clear whether this will be a required part of the accounting procedures for obtaining credit.
- Only tree species were included in the actions, and early growth rates for all species are very uncertain. The use of shrubs or native tall grasses are other good possibilities that should be examined for cost effectiveness, especially in relation to shelterbelts and plantations established as a feedstock for bioenergy, and for environmental purposes.
- Only direct planting and maintenance costs were estimated - costs and potential benefits which have not been accounted for include: forest protection costs, afforestation program costs; the net revenue of harvesting and use of mature stands; carbon monitoring, measurement and verification costs; and the potential value of carbon credits.
- The level of incentives needed to achieve the targeted level of planting is very uncertain and will have to be investigated more throughly as program development occurs - it is the level of incentives that is offered that will have the most impact on the total land afforested. In particular, a relatively ad hoc assumption was used in the analysis of the actions to indicate the scale of the opportunity costs of afforestation.
- The use of public land for afforestation was not addressed in the analysis. In certain provinces, such as BC and Alberta, large areas of public land are leased for range and this might be suitable for afforestation.
- Further study is needed of the implications of the various end uses as well as the market opportunities associated with afforestation.

- A useful way to gather more in-depth information would be regionally-targeted surveys of rural landowners to determine their level of interest, motivation, land availability and its current condition, and the level and structure of incentives that would be required for their participation in afforestation.

Relationship of Planting Actions to Each Other and to Other Actions

- The afforestation actions complement each another. The two Prairie actions are qualitatively different - the shelterbelt action is expected to be adopted by a larger number of farmers but with much smaller planting areas per farm that will be the case with plantations. As well, the shelterbelt action focuses on soils that are of medium and poor quality for trees while the block plantation action focuses on good soil areas.
- Afforestation could be considered as a possible source of future energy supplies, and in this respect this action may complement fuel switching actions in the forest sector and in other sectors. This possibility is heavily dependent on relative fuel prices and on government policies to encourage the use of bioenergy.

4.2.9 Stakeholder Views

As noted above, there are still significant uncertainties about the precise cost and impact of afforestation, especially in the first commitment period. There are a variety of carbon accounting issues which still need to be resolved through negotiations because of the likelihood that fast-growing tree species will be harvested in or soon after the first commitment period. The implications for carbon credits under alternative negotiation outcomes would have to be further investigated, as part of afforestation program development. Stakeholders have expressed varying views on the implications of these uncertainties.

Some Table members believe an afforestation program involving planting fast-growing tree species should be part of core set of initiatives to help Canada reduce or offset its ghg emissions. They believe that afforestation using slower growing species should also be pursued. While more expensive to establish than afforestation using other species, the use of fast-growing species would increase the amount of carbon sequestered in the first commitment period. In general, there is still considerable uncertainty about the potential involvement of landowners and others in afforestation, but it is likely that the forest products industry will be very interested in participating in this type of afforestation and using the wood either for energy or products such as oriented strand board.

Other Table members feel there are still too many uncertainties to warrant moving forward with afforestation for carbon credits. The concern is that many of the unknown factors may significantly reduce the net carbon benefit. They include uncertainties related to:

- accounting and responsibility for carbon already on-site prior to afforestation, or that would accumulate in the absence of an afforestation program;
- deforestation debits that would result from program "drop-off" as landowners convert their afforested lands back into some other use;
- emissions due to site treatment, as well as from the harvesting, processing, and transportation of products manufactured using trees from afforested areas, and
- treatment of carbon credits and debits following harvest.

Other unknowns relate to the overall suitability or practicality of afforestation programs for carbon credits. These unknowns include:

- the extent of effective engagement of landowners;
- uncertainties about site selection, including biophysical limitations as well as potential conflicts with other land-use objectives; and
- environmental and health concerns regarding species selection and site treatment.

In addition, specific concerns related to fast-growing plantations include significant concerns around environmental impacts and the general appropriateness of fast-growing plantations. As well, some Table members feel that there is little point in highlighting fast-growing plantations as a distinct option, because while there is a short term advantage to using fast-growing species, there is no demonstrated long-term advantage to generating afforestation credits with fast-growing species as opposed to traditional native species.

4.3 CURRENTLY IN PROTOCOL WITH HIGHLY UNCERTAIN DEFINITION - REFORESTATION

4.3.1 Analytical Issues

Uncertain Negotiating Outcomes

The changes in carbon stocks between 2008 and 2012 on areas reforested since 1990 may be used to offset Canada's target in the commitment period. However, the definition of reforestation under the Kyoto Protocol is still to be negotiated internationally. There are two distinctly different interpretations that are critical to any forecasts of estimates of future potential. Many countries think that reforestation should be defined similar to the definition in the IPCC ghg emission inventory guidelines. Canada's suggested wording is consistent with the definition of the United Nations Food and Agriculture Organization.

Canadian working definition:	**a land-use practice that, through the re-establishment of a stand of trees, forms a forest**
FAO definition:	**the establishment of a tree crop on forest land**
IPCC definition:	**planting of forests on lands which have, historically, previously contained forests but which have been converted to some other use.**

At issue in these contrasting definitions is whether the re-establishment of trees after harvesting, i.e., regeneration, is included under the Protocol as reforestation or not. If a definition similar to the IPCC definition is accepted internationally, then reforestation will in fact be "re-afforestation", or afforestation in the sense that it is presented in Section 4.2. Clearly, most areas in Canada that are currently without tree-cover and are available for tree-planting (e.g., marginal farmlands) were at one time "historically" forested.

If the narrow, non-forestry related IPCC definition is adopted, then there are essentially no "forestry" activities under Article 3.3. of the Protocol, which refers to direct human-induced "land-use change and forestry activities of afforestation, reforestation and deforestation". By limiting the definition of reforestation to a solely land-use change definition, those Parties for whom forests require on average 100 years to reach maturity receive credit for a very small sink in the commitment period. At the same time, including deforestation occurring in the commitment period, without balancing this against the growth in the rest of the managed forest, can, as shown in the recent SBSTA workshop in Rome, result in perverse consequences. More specifically, a Party may be required to report an increase in emissions (i.e., from deforestation) when overall, as a result of good forest management on the rest of the forest, the forest has continued to act as a sink, and credit should be given. Under the FAO or Canadian working definition for reforestation, and assuming that credits are only obtained on the Kyoto Forest, a potential credit could be obtained even when the total volume of carbon stocks on the managed forest is stable or declining.

Many Sinks and Forest Sector Table members hold strong and divergent views on which definition is the 'right' definition, as well as which one is the most likely to be agreed to internationally. Some have argued that it is inconceivable that reforestation, defined as regeneration, would be agreed to, without adding in harvesting as the balancing source to the reforestation sink. The problem is that the "balance" to harvesting is not the growth on areas reforested since 1990, but is the total annual growth of the managed forest. Under sustainable forest management, the volume harvested equals the growth of the forest, given certain assumptions about age class distributions and other factors.

Another argument that has been put forward against defining reforestation as regeneration after harvest is that currently the IPCC guidelines consider the use of biomass for energy to be CO_2 neutral, because the biomass is assumed to come from a sustainable forest management regime. Therefore, to obtain credit for reforestation/regeneration, and to have no responsibility for a debit when using the biomass as fuel (when the reason that there is no debit is that it is assumed to a sustained and renewable resource) seems to be counter-intuitive. Clearly, Canada is only one country of many who will be party to negotiating the definitions, and any forecast of the outcome of negotiations is speculation at this point.

The BAU estimates of CO_2 sequestration from reforestation are presented in the Sinks Table Options paper and summarized in Table 4.3.1. These estimates do not reflect the impact of "incremental" or "enhanced" regeneration, but are estimates of the net CO_2 benefits under alternative definitions under the Protocol that could be used to offset Canada's commitment, without further investment or policy changes. Because of the uncertainty over definitions, the net CO_2 sequestered is presented under the two divergent definitions. If reforestation is defined according to the IPCC definition then the BAU estimate for reforestation is equal to the CO_2 sequestration from BAU levels of planting on agricultural land (assumed for now to equal zero).

If reforestation is defined as regeneration after harvest (i.e., the FAO definition), then BAU estimates for 2010 are in the -2 to 13 Mt/y range depending upon carbon stock components. Which components of carbon stocks will be counted is critical, since there are indications that changes in below-ground and soil carbon cause areas to be a net source for 10 to 20 years after harvest, even if the slash and litter from harvesting is excluded from the calculations. Because harvesting is excluded from the Protocol, there have been suggestions that the slash and litter resulting from harvest should not be considered part of the carbon stocks on the site during reforestation. There are practical difficulties with this notion, particularly related to measurement and monitoring.

In Table 4.3.1 there is a large discrepancy between the estimates for eastern and western Canada under the FAO definition, reflecting differences in the methodologies and assumptions used to derive the estimates. Further refinement of these numbers clearly is needed. The above-ground BAU estimates are reasonably consistent with those reported in the Forest Sector Table and Sinks Table Foundation Papers. Note also that these BAU estimates include both natural regeneration after harvest and planting and seeding. Approximately 50% of harvested areas are regenerated naturally after harvest. Although it is possible that this type of definition of reforestation would exclude natural regeneration, the industry generally "assists" regeneration by post-harvest treatments such as scarification. In addition, there is an increasing use of specific harvest techniques such as shelterwood systems to promote natural regeneration. Also shown for reference is harvest volume converted to CO_2-equivalent emissions. Clearly this would add a huge debit to Canada's target.

Table 4.3.1
BAU Estimates of Reforestation Under Two Alternative Definitions, Mt CO_2 / y

Definition of Reforestation	Carbon Stock	2010 Mt CO_2 / y	2020 Mt CO_2 / y	Assumptions
FAO definition: regeneration after harvest				
Western Canada	a Above ground biomass	2	8	Based on harvest forecast to 2020, only sequestration due to reforestation since 1990 is included
	b Above and below ground biomass, and soil	2	10	
Eastern Canada	a Above ground biomass	11	35	Based on harvest forecast to 2020, only sequestration due to reforestation since 1990 is included
	b Above and below ground biomass, and soil	-4	27	
Total Canada	a Above ground biomass	13	42	Based on harvest forecast to 2020, only sequestration due to reforestation since 1990 is included
	b Above and below ground biomass, and soil	-2	37	
IPCC definition: re-afforestation				
Total Canada	All forest carbon stocks	0	0	Considered as afforestation
Harvesting	Above ground biomass only	-210	-210	1996 harvest volumes of 183 million m^3 converted to CO_2 (assuming emissions in same year as harvest)

International agreement may not be reached until COP6 or later on the definition of reforestation. In addition, it is not yet known which carbon stock components will be counted for the purposes of determining compliance with the Protocol. It is clear that carbon sequestration from above-ground tree biomass is included, but there is some uncertainty as to whether carbon sequestration in soils and below-ground biomass will be included. Future negotiations will also develop guidelines, rules and procedures for measurement, monitoring and verification of sequestration. The costs of these activities will vary according to the requirements, the type of reforestation and reforestation policies. These costs were not assessed by the Forest Sector and Sinks Tables.

The following discussion and options refer only to the FAO definition of reforestation, i.e., "the establishment of a tree crop on forest land." Under the IPCC definition, virtually all of the planting programs described in Section 4.2 on afforestation would be considered reforestation, and none of the activities in this section would be eligible for credit under the Kyoto Protocol.

Accounting Issues

There are significant accounting and measurement issues associated with reforestation if defined as regeneration after harvest. One of these is how to determine carbon stock changes due to regeneration if harvesting methods other than clear-cutting are used. In the case of clearcuts, a definite area is cleared of all standing above-ground woody biomass (i.e., trees), and the change in carbon stocks over time is based on the growth of planted or naturally regenerated young trees (the monitoring and measurement of woody debris and below ground and soil biomass is not as straightforward). However, if an area is harvested using a partial cutting method (i.e., not all of the trees are removed), then it is not straight-forward to measure the change in stocks during the commitment period. The main problem is that it is difficult to specify what portion of any growth on a site that has been partially cut is due to anthropogenic activity and what portion is "natural". Excluding partially cut sites from the reforestation definition is not a solution as it would provide an incentive to favour clear-cutting over other harvesting methods. Canada currently uses partial cutting on approximately 10% of areas harvested, although the proportion is growing. Many other countries such as the US harvest most areas using partial cutting. Given the wide range of harvesting methods in use around the world, this issue will need to be resolved for both political and environmental reasons, should reforestation be defined as regeneration after harvest.

Another question (also valid for afforested areas) is how to account for the change in carbon stocks when an area within the Kyoto Forest (i.e., regenerated since 1990) is then harvested, given that harvesting is not currently included in the Protocol.

Policy Environment

Canada's forests are predominantly publicly owned. Approximately 71% is owned by the provincial governments and 23% by the federal and territorial governments. Harvesting on this public land-base is regulated through various tenure arrangement with private companies. Companies are regulated in terms of amounts and areas harvested per year as well as the ongoing management and regeneration of sites after harvesting. Forests are managed for multiple values and provinces and companies are working towards improved sustainable forest management practices. Harvesting on private lands is not regulated, although some provinces are starting to introduce incentives to improve forest management on private lands. In addition, in some provinces where companies operate on both public and private lands, the proper management of their private lands is linked to their tenure rights on public lands.

The implications of the ownership and management regimes in Canada is that there is currently little flexibility to increase carbon storage through changes in reforestation practices. Companies are bound by codes of practice and silvicultural prescriptions to regenerate forests in particular ways. Two elements of regeneration strategies that have significant impact on sequestration potential are species selection and spacing or density management. These could be investigated to determine the impact of modifications to enhance carbon storage. However any changes would need to be balanced with the myriad of other considerations and values that are taken into consideration in forest management.

Choice of Species

Assuming that reforestation includes regeneration after harvest, a key determinant of the total sequestration that will occur is the choice of species. Species traditionally used for forestry, and for which seedling stock is relatively abundant, have relatively low sequestration rates in the Canadian climate. Faster growing species such as hybrid poplar can reach peak annual carbon sequestration rates in 10-25 years. The fastest growing tree and shrub species can take as little as 5-8 years. Provincial agencies generally require that areas are regenerated to the same species as what was harvested, or in some cases, stand conversion to another more suitable or more commercially viable species is carried out.

Although there is still uncertainty as to how reforestation credits will be measured, its seems likely that the total carbon credit available on a given site will be limited to the maximum (rather than the total) volume of carbon that accumulates on that site (i.e., over one rotation). Using fast-growing species, therefore, while having potential to increase carbon credits during the first commitment period, may not result in a net long term benefit.

Whatever the species chosen, a difficulty in estimating the sequestration impact of reforestation actions is the lack of good information on tree growth curves, especially in the first two decades after planting which is the key period for determining the impact in the first commitment period. This introduces an unknown degree of uncertainty into the estimates of sequestration due to the actions.

Impact on Environment

Although negotiations are not yet completed on the RAD and definitions are not yet determined, there is an important environmental aspect of reforestation that should be noted. If reforestation is defined as regeneration after harvest, the net impact on the atmosphere is that more industrial carbon emissions will be emitted, since the amount of CO_2 sequestration from reforestation will be offset from Canada's target and industrial emissions will not need to be reduced by as much. Under this definition, Canada essentially gets a "windfall gain" because it has been harvesting and regenerating approximately 1 million hectares per year since 1990 and therefore Canada would get this credit without necessarily increasing the amount of carbon stored in its forest over the long term. This definition of reforestation allows countries in essence to defer taking actions that will have an impact on CO_2 concentrations in the atmosphere.

There are actions that can increase the carbon sequestered on regenerating sites, i.e., incremental increases over and above that which would normally carried out. These actions may have some beneficial impacts on the atmosphere, although their impact in the long run is not clear and will depend upon a variety of factors, including species and rotation age. However, the potential incremental amount from these actions is small compared to the total carbon sequestered through reforestation.

From the point of view of Canada, however, reforestation can provide a significant contribution to meeting Canada's target in the first commitment period under the National Implementation Strategy, under a definition that includes regeneration after harvest.

There is also some concern that a definition of reforestation that includes regeneration after harvest could have the perverse effect of increasing the rate of harvest (for which there is no debit under the Kyoto Protocol at present) in order to obtain credit from reforestation. This is unlikely to occur in countries like Canada where forests are predominantly publicly owned and managed, and where significant codes of practice and regulations are in place. This concern is most relevant for private lands that are not regulated or in countries that do not have or enforce adequate regulations to ensure sustainable forest management practices.

4.3.2 odification of Reforestation Methods to Increase Carbon Sequestration After Harvest

Note that the discussion here assumes that negotiations result in a definition of reforestation similar to the one used by the FAO and proposed by Canada. The actions discussed are those which will potentially increase carbon sequestration on areas regenerating after harvest since 1990, as well as on areas to be harvested in the future, relative to the BAU case. Because of the considerable definitional uncertainties, any actions or policies to facilitate actions must be considered carefully before implementation. Those actions that do not adversely affect other objectives, or that are cost-effective and complementary to other objectives, are obvious contenders. Actions aimed at maximizing on-site carbon sequestration and storage over the long term are not the same as, and in some cases may conflict with, actions aimed at maximizing sustained yield of timber. Multiple objectives will need to be considered in determining the best strategies to adopt.

Use of Genetically Enhanced Trees

One possibility is the use of genetics and tree breeding programs to develop faster growing trees. The main driving factor for the development of faster growing and disease resistant trees has been and will continue to be wood supply for the forest industry. The first generation seed orchards began to yield operational quantities of seed in the early 1990's. The volume increases of 10 to 30 percent are expected to result, and further increases should result as tree breeding programs continue. By 2005, about half of all planting is expected to be using faster growing trees. Efforts to accelerate tree-breeding programs and development and use of faster growing trees could contribute to meeting Canada's Kyoto target. The cost of this needs to be investigated but a rough idea of the possible carbon impact can be derived using the same assumptions used to derive the BAU estimates. The effect in the first commitment period of a 15% increase in tree growth on all areas planted/seeded since 2000 is an increase in the annual sink of about 0.5 Mt CO_2 in the first commitment period.

Density Management

There has been considerable research carried out in recent years on the impacts of density management, including juvenile spacing and pre-commercial thinning. Juvenile spacing or pre-commercial thinning is the deliberate removal of excess stems from over-stocked stands of young trees (usually 10 to 14 years old) in order to reduce competition for space, light, water and nutrients. A number of provinces have produce managed stand yield tables for commercial tree species for various planting densities, or spacing regimes. While current guidelines and research is aimed at maximizing commercial volumes at harvest, there is some research that indicates significant biomass gains can result from modifications in planting or spacing regimes.

Species Choice

As noted above, species selection can have a significant impact on carbon sequestration. In particular, some species that are faster growing may be shorter lived, but reach higher rates of CO_2 sequestration earlier than others (e.g., poplar). Most provincial agencies have requirements for regeneration after harvest that relate to species selection. Generally the same species must be regenerated as was harvested, unless stand conversion is desired. Any species changes to increase CO_2 sequestration would need to be considered in light of other objectives such as final products, biodiversity, aesthetics, etc.

Increased Use of Planting Instead of Natural Regeneration and Seeding

After harvesting, forests in Canada are regenerated by either planting (45%), seeding (5%) or natural regeneration (50%). Planted trees generally reach maturity 10 to 13 years earlier than naturally regenerated stands. In part, this is because trees that are planted are already several years old but, in addition, some form of chemical or mechanical site treatment reduces weed competition and allows young trees to establish themselves earlier. Planting also offers the opportunity to use genetically enhanced seedlings, or to change species to one more suited to the site.

However, most provinces have numerous environmental objectives in addition to those related to climate change, and many of these are consistent with a high percentage of naturally regenerated areas. It is also the most cost-effective method of regeneration in most areas where it is carried out.

Expected Action Cost and GHG Impact

Little analysis has been carried out on the potential ghg impacts and related costs of these types of activities. The bulk of the ghg reduction benefit from reforestation will be attained under the business-as-usual scenario if the definition of reforestation includes regeneration after harvest. Obviously, none of these actions would be carried out (at least for the purposes of increasing sequestration to meet Canada's target) if the Protocol does not allow credit for reforestation as defined this way.

Barriers to Implementation

- Negotiation outcomes, in particular the definition of reforestation, will determine whether the net carbon sequestration from these actions counts towards Canada's target. Which components of carbon stocks will be counted is also critical.
- Other values in the forest, including biodiversity, wildlife, aesthetics, stream quality etc, may be adversely affected by some of these actions. Sustainable forest management practices strive to achieve a balance among many objectives.
- Changes to species mix must take into consideration potential climate change impacts on growth rates and insects and disease factors.
- Costs of planting are higher than natural regeneration or seeding. In addition, some sites are inappropriate for planting due to location, accessibility or site conditions. Other activities such as juvenile spacing are also rarely practiced due to cost.
- Who owns carbon credits on public lands is an issue that will need to be resolved. For example, if a company has a forest management agreement with the province, and invests its own money to increase carbon sequestration, they need to be assured of obtaining the C credit. A related question is who "owns" the risk of losses and carbon debits. In addition, issues related to security of long-term tenure rights for forest companies are relevant.
- On private lands, woodlot owners can only write off the costs of planting if it occurs in the same year as the harvest, which is a often difficult and therefore a disincentive to planting. In general, tax treatment of woodlots is unfavourable compared to agriculture and grazing. Farmers can carry forward tax losses while woodlot owners cannot.

Policy Requirements

- Since most harvesting and reforestation is carried out on public lands, the provincial governments will be the main sources for policy changes
- Incorporating ghg sequestration objectives into forest management planning objectives is possible, but only taking into account the balance of other values and objectives on public lands.
- If companies can obtain carbon credits for the GHG sequestered from actions to increase reforestation, then this may provide sufficient incentive to change practices.
- Alternatively, provincial governments could offset private company costs for practices that increase ghg sequestration.
- Provincial regulations to control over-harvesting on private lands to prevent owners from harvesting in order to obtain credit for reforestation may be required.
- Provincial regulations mandate prompt regeneration of harvested areas, yet there is still 3 million ha of area that is not sufficiently restocked (NSR). This area is declining over time as backlog NSR is planted, but new NSR is added when areas do not regenerate in a reasonable amount of time. In order to ensure prompt regeneration of sites, more consideration of regeneration systems including modification of harvesting techniques is needed.

Regional and Intra-Sectoral Implications

- The area harvested per year in Canada is approximately 1 million ha. Quebec, Ontario and BC represent approximately 75% of this. Harvest volumes are highest in B.C., followed by Quebec and Ontario. B.C. has the highest productivity (annual growth rates) particularly on the Coast. Estimates show higher carbon sequestration in the eastern provinces than in the west, but this is largely a function of different methodologies and assumptions used by the consultants.
- Any increases in ghg sequestration due to changes in reforestation techniques may also increase merchantable wood volumes, which will increase wood supply for the forest products industry. Some changes may result in a shift from sawlogs to pulplogs or vice versa. Changes in species composition will impact final products.

Competitiveness, Economic and Social Implications

- Increasing costs of reforestation, if borne by forest companies, would increase delivered wood costs and negatively impact competitiveness.
- Modification of reforestation practices could generate some increases in seasonal employment for tree-planters and forest management contractors.
- Significant increases in growth due to changes in regeneration practices could yield long-term benefits in terms of increased harvesting and related forest product production.

Environmental and Health Impacts

Modifying reforestation methods to focus on increased CO_2 sequestration is likely to result in a range of environmental costs and trade-offs with other forest management objectives. These potential trade-offs include biodiversity conservation and ecosystem management objectives (e.g. provision of stand structural diversity and habitat); aesthetic landscape and recreation planning; stream and water quality considerations; and long term regeneration objectives (e.g. use of native tree species to minimize biological risks and diseases). The precise nature and extent of these types of trade-offs is uncertain and is an important information gap.

Extent of Use of Same or Similar Actions/Measures in Other Countries

- Many countries oppose a definition of reforestation that includes regeneration after harvest. It is unknown at this time if any countries are developing plans to increase reforestation growth to respond to the Protocol.

Further Analytical/Study Needs

- Further work on ownership issues around carbon credits is needed.
- Improved growth and yield information for second growth stands is needed. In particular, the C sequestered in young stands (first 30 years of growth) is poorly understood, and the difference in growth between naturally regenerated versus planted forests, are poorly understood.
- The carbon sequestration potential and the related cost per tonne from the four sub-actions needs to be determined for all carbon pools. While a fair amount of information is known about the impact of these actions on above-ground biomass (predominantly merchantable tree volumes) in specific regions and for specific species, the impact on a broad national scale is not known. In addition, the impact on soil carbon as well as below-ground biomass and dead organic matter carbon pools needs to be analysed, which will likely involve collection of basic site-level data.

Relationship to Other Actions/Measures

- This action is related to afforestation and to the managed forest actions.

Stakeholder Views

Consideration of modifications to reforestation methods to increase carbon sequestration may increase the planning and resource demands on public forest managers, adding to considerations of multiple objectives and other legal and policy requirements (e.g. codes of forest practice). There may also be concerns from community groups and stakeholders with direct interest in the management of public forests for other values (e.g., recreation and hunting associations).

As noted earlier, there is disagreement among Table members on the appropriateness of the proposed Canadian definition of reforestation in the Kyoto Protocol. In particular, the views and concerns of environmental non-governmental organizations can be summed up as follows:

1. The proposed definition undermines the Convention, for the following reasons:

    - It provides for a large carbon credit without there necessarily being any increase in the amount of carbon stored in the forest over the long term. In fact, in certain cases - such as the conversion of high-volume old growth stands - there would be a significant reduction in the total volume of carbon stored on the site, but the "reforestation" credit would still apply.
    - It allows for the double counting of carbon credits related to fossil fuel substitution.

2. The proposed definition would create potentially perverse incentives running contrary to sustainable forest management:

    - By providing a credit that increases as the harvested area increases, it creates an incentive to increase harvesting levels, having a potentially negative impact on a range of environmental and social values. This is of particular concern on private lands.
    - There is as yet no clear understanding of how reforestation credits would apply on lands that have been harvested by selection cutting methods; however, in general forestry parlance these areas are not considered to be "reforested." If they are excluded from eligibility for Kyoto credits then there would be a substantial incentive to avoid using these methods in order to obtain the "credit for clearcuts."

4.4 INCLUDED IN PROTOCOL WITH MODERATELY UNCERTAIN DEFINITION - DEFORESTATION

Deforestation is one of the three activities (reforestation, afforestation and deforestation) currently included under Article 3.3 of the Kyoto Protocol. Changes in carbon stock in 2008 to 2012 resulting from these activities since 1990 will be netted against a country's target. As noted earlier, this creates an imbalance between sinks and sources. Countries will have to account for a potentially large carbon debit per hectare as a result of deforestation (i.e., clearing mature standing timber), but obtain only a very small credit from afforestation and reforestation, because trees will still be very young in the first commitment period as a result of the "since 1990" caveat applied to the RAD activities in the Protocol. Under a managed forest approach (as discussed in section 4.5), this is less of an issue, as there is a more complete accounting of all carbon flows.

Deforestation in the 2008-2012 time period will be counted as a source of CO_2 emissions, and will thus increase Canada's emissions during the commitment period. Deforestation is not included in the 1990 baseline level. As such, deforestation represents a liability, in the sense that emissions from deforestation will increase the overall level of emissions of Canada's business-as-usual scenario above the 1990 baseline level.

The identification of potential policies and actions to reduce current rates of deforestation will be an important part of Canada's overall climate change strategy. Policies to reduce carbon sources from deforestation activities will need to be balanced against other economic and policy objectives, such as regional economic development and employment generation in those regions where deforestation is occurring. However, there is a critical lack of concrete information on the extent and location of deforestation, which precluded the development of specific policy proposals for this options report.

4.4.1 Analytical Issues

Uncertain Negotiating Outcomes

International negotiations on the definition and interpretation of deforestation under the Kyoto Protocol will be an important determinant of what types of deforestation activities will counted as a source of CO_2 emissions. The IPCC guidelines do not provide an explicit definition of deforestation although they do make reference to the fact that 'conversion of forests is also referred to as deforestation' (IPCC, 1997). Consistent with this implied definition, the UNFCCC Secretariat has suggested that deforestation might be defined as **"the conversion of forest land to other land-use"** (UNFCCC Secretariat, 1998). They have also proposed two alternative refinements of this definition: i) "the direct human-induced change of land-use from forest to other land-use OR the depletion of forest crown cover to less than 10 per cent"; and ii) "the direct human-induced change of land-use from forest to other land-use and the depletion of forest crown cover to less than 10 per cent". This clearly illustrates a key issue related to the definition of a forest (and hence deforestation) – is it based on land-use or land-cover?

International agreement may not be reached until COP6 or later on the definition of deforestation. If the outcome of international negotiations is to define deforestation in terms of the depletion of forest crown cover to below a given level (such as 10 per cent, for example) rather than a change in land use, Canada's emissions from deforestation under the Kyoto Protocol will likely be greater. This is because there are presently a range of development activities that probably would not be considered a change in land use, such as the establishment of utility lines or forest access roads, but that remove small stands or corridors of trees to below 10 per cent of crown cover.

Canada has proposed a working definition of deforestation as **"a change in land-use that removes a forest"** which would include forest conversion for permanent land-use changes such as agriculture and rangeland activities, as well as development of permanent infrastructure, such as a highways. However, it would exclude areas that did not change the land-use, such as construction of forest management access roads. It is important to point out that harvesting is not considered deforestation, as long as an area regenerates back to forest.

It is not yet determined which carbon stock components will be counted as emissions for the purposes of determining compliance with the Protocol. It is likely that carbon emissions from above-ground biomass following deforestation will be counted, but there is some uncertainty as to whether releases from below-ground biomass and dead organic matter (litter, coarse wood debris and humus) will be included. Which components of carbon stock will be counted will be critical to determining the impact of deforestation as a source of CO_2 emissions. The inclusion of litter, coarse woody debris and 10 per cent of the humus pool, for example, may double predicted estimates of annual CO_2 emissions from deforestation activities (Robinson *et al.*, 1999). There is the added question of whether ongoing emissions from areas deforested in 1990-2007 will be counted if they occur in the first commitment period - some carbon stocks, such as below ground and soil carbon, will continue to emit CO_2 for many years after deforestation.

Future negotiations will develop guidelines, rules and procedures for measurement, monitoring and verification of biological sources of CO_2 emissions. The cost of policies to monitor changes in deforestation activities will vary according to the requirements and types of deforestation. These costs were not assessed by the Forest Sector and Sinks Issues Tables.

BAU Estimates of Deforestation Activities

Information on the extent of deforestation in Canada is limited, but we do know that it occurs across a range of industry and residential sectors on both public and private forested lands. Major sources of tree removals include agriculture, mining, forestry access roads and residential and urban development (see Table 4.4.1). This provides a wide range of activities that affect land-use and/or land-cover. It is unlikely that all of these activities or categories would be included in the definition of deforestation to be negotiated under the Kyoto Protocol.

Table 4.4.1
Types of Deforestation Activities

Agriculture and Forestry Activities	Industrial and Urban Development
• land clearing for range • land clearing for agriculture • range encroachment of forest • shelterbelt removal • livestock destruction of riparian forest • construction of forest management access roads and associated infrastructure	• road and rail development • mining and petroleum development (including oil sands development, open pit mining and seismic lines) • flooding of forests for hydroelectric head ponds • utility corridors, rights-of-way • air strips • recreational uses such as ski resorts, golf courses and parking lots

There is limited information available in Canada on the current and recent (since 1990) extent and spatial location of deforestation as this information is not explicitly monitored by federal or provincial agencies. The Sinks and Forest Sector Tables commissioned a study to provide estimates of carbon losses from deforestation from a variety of activities. The estimates, while based on best available information, including a survey of relevant government and industry representatives, are still highly uncertain. Table 4.4.2 summarizes these estimates (Robinson *et al.* 1999). We assumed, for the purposes of evaluating the impact of deforestation in the first commitment period, that current deforestation rates and CO_2 emission levels by sector will remain unchanged.

A key requirement for meeting Canada's emission reduction commitments under the Kyoto Protocol will be to further develop measurement and reporting tools to monitor changes in deforestation activities and associated CO_2 emissions. Previous estimates of CO_2 emissions from forest clearing for agriculture and urban development were reported in the Sinks Table and Forest Sector Table Foundation papers, and ranged from between 3 to 19 Mt of CO_2 per year for releases from above-ground biomass and soil carbon. The estimates in Table 4.4.2 narrow the range somewhat, to 9 to 14 Mt of CO2 per year for above-ground biomass alone.

Table 4.4.2
Deforestation Estimates for Major Sectors
(CO_2 emissions from above-ground biomass only)

Source	Low - High Estimate (hectares per year)	Low - High Estimate (Mt CO_2 per year)	Provinces Where Likely to be Most Significant
Agriculture	10,300 - 30,800	2 - 6	BC, AB, SK, ON
Forestry	21,600 - 21,600	4	BC, ON, NB, NS
Urban development	3,600 - 3,600	1	BC, AB, ON, PQ
Transportation	1,200 - 1,200	0.2	
Recreation	<100 - 500	<0.1	
Mining and petroleum	10,900 - 12,700	1 - 2	AB
Electricity generation	7,000 - 10,100	1	PQ
Total	**54,600 - 80,500**	**9 - 14**	

Table 4.4.3 shows the potential impact on BAU estimates of alternative definitions of deforestation, i.e., land-use change (excluding forest roads) and a land-use change/land-cover definition. Based on these estimates, it is evident that forest clearing for agriculture, mining and petroleum development and electricity generation are major causes of deforestation under a definition based on a change in land-use. Mining and petroleum deforestation largely arises from oil exploration and infrastructure development in Alberta - uncertainty in these estimates arise from a lack of information about the ranges of sizes of new mines. Under a land-use change definition (i.e. excluding forestry roads), Canada's emissions from the three major sources would be between 4 and 9 Mt CO_2 per year.

It should be noted that afforestation programs, discussed in Section 4.2, could be a future potential source of deforestation, if the land does not permanently remain in forest cover. If owners convert to tree cover, but then later decide to return the land to agricultural crops, this would result in a deforestation debit (equal to the carbon credit accrued for the afforested area).

Table 4.4.3
Impact of Alternative Deforestation Definitions

Possible Definition of Deforestation	Sources by Sector (Mt CO_2 per year)	Total Emissions (Mt CO_2 per year)
a) Land use change only	*Major sources*	
	Agriculture	2 - 6
	Mining and petroleum development	1 - 2
	Electricity generation	1
	Total	4 - 9
	Minor sources	
	Urban development	1
	Transportation	0.2
	Recreation	<0.1
	Total	1
b) Crown cover/partial forest removals (e.g. forestry roads) only	Forestry	4
c) Land use change and crown cover/partial forest removals	a + b (all sources above)	9 - 14

Forestry

The estimates show that the agricultural and forestry sectors are the two major causes of deforestation and together account for between 6 to 10 Mt CO_2 per year. The estimate for the forest sector of 21,600 ha/year represents approximately 2.2 percent of the annual area harvested. This estimate is based on a report by CCFM (1996), and summarizes provincial estimates of the amount of non-productive land that is produced annually as a result of "...roads, landing and non-forestry developments that have no timber production objective. These areas also include land where erosion, a rising water table, or other forms of site degradation make a site unsuitable for forestry purposes" (CCFM, 1996). Most of the area consists of forest access roads.

The REGEN database, from which these estimates are derived, is updated on a regular basis, and most provinces base their estimates of non-productive land increases on a percentage of area harvested that averages around 4% but ranges from 3 to 7%. The comparable percentage for BC (from a different source) is around 5%. Alberta, Quebec, PEI, Yukon and NWT do not report creation of non-productive land. If the average of 4% is applied to total harvest area in Canada, the area deforested annually due to infrastructure development could be approximately 40,000 ha per year or almost twice that reported in Table 4.2.2. Both of the estimates exclude secondary roads, landings and skid trails that are generally decommissioned (i.e., rehabilitated and put back into forest).

As noted above, the removal of trees for forest access roads and associated forestry infrastructure may not be considered deforestation if a definition related to land-use change is adopted. A definition that would include forest roads as deforestation would penalize younger countries such as Canada which have less developed infrastructure. And certainly over time, as the industry moves to harvest maturing second-growth stands, this rate of road building should decline. It should also be noted that sustainable forest management practices have in some cases led to an increased requirement for roads, e.g., adjacency and "green-up" constraints, coupled with smaller cut block sizes, mean that annual harvest areas for a company are spread out over a larger area.

Environmentalists believe that all roads should be considered deforestation, and object to any definition which would distinguish between roads built for the purpose of removing timber (which would not be considered deforestation) and roads built for other purposes (which likely would be considered deforestation). They believe that, from a climate change perspective, this is an arbitrary and illogical distinction to make.

Agriculture

Forest conversion for agricultural activities falls within either definition of deforestation proposed by the UNFCCC Secretariat and hence would be a direct source of CO_2 emissions during the first commitment period. Estimates by Robinson *et al.* (1999) of deforestation in agriculture based on a comparison of land area statistics from the Agricultural Census for 1991 and 1996 are shown in Table 4.4.4. In some provinces, the total area on Census farms has increased greatly over the five-year period. Unfortunately, the data do not allow any inference as to the source of the agricultural land (i.e., whether it was forested or not). Nevertheless, some crude inferences can be made to demonstrate typical orders of magnitude of deforestation activities for agricultural purposes. Excluding those provinces that show a decline, the sum of the increases in total agricultural land area is 1,027 km^2/yr. Assuming only 20% (i.e., half of the 40% of the national land base that is currently forest) of the 1,027 km^2/yr is derived from forests, this would add 205 km^2/yr to the deforestation statistics. Allowing for further uncertainty of ±10% provides upper and lower bounds of 103 and 308 km^2/yr.

Table 4.4.4
Change in the Area of Total Agricultural Land in Canada, 1991-1996

Province	1991 hectares	1996 hectares	Change ha / y	Change km^2 / y
British Columbia	2,392,350	2,520,794	25,689	257
Alberta	20,811,074	21,028,729	43,531	435
Saskatchewan	26,865,581	26,568,586	(59,399)	(594)
Manitoba	7,725,017	7,730,941	1,185	12
Ontario	5,451,398	5,603,405	30,401	304
Quebec	3,429,622	3,431,909	457	5
New Brunswick	375,632	376,386	151	2
Nova Scotia	397,033	392,472	(912)	(9)
Prince Edward Island	258,875	264,817	1,188	12
Newfoundland	47,353	43,588	(753)	(8)
Canada	67,753,935	67,961,629	41,539	415

Source: Statistics Canada. Excluding those farms in the 1996 Census that grow Christmas trees only.

A separate study (IISD, 1999) was conducted to try to better understand the agriculture/forestry interface and to determine whether there were agricultural or land-use policies in place that might be encouraging deforestation in this sector. An *ad hoc* survey of provincial contacts tended to support the Robinson *et al.* (1999) study, except for Ontario where the numbers were thought to be too high, and for Saskatchewan where they were thought to be too low. In addition, various Agriculture Table members and provincial Forest Sector and Sinks Table members indicated that the Robinson *et al.* (1999) numbers may be overestimates, although no better numbers could be offered.

Given the potential significance of agricultural land clearing as a source of deforestation in Canada (accounting for between 20 to 40 per cent of total current emissions from deforestation as presented in Table 4.4.2), and the likelihood that it will be included under the Kyoto Protocol, further analysis into possible actions to reduce clearing of forests for agricultural development should be undertaken.

4.4.2 Policy Environment

It is evident that deforestation occurs in a wide range of sectors, and for many different economic and social objectives, including regional and economic development, employment generation and provision of housing and recreation facilities. Policies targeted at reducing sources of CO_2 emissions from deforestation would need to be balanced against a broad range of activities and policy goals of governments, as well as the interests of stakeholders dependant upon these activities for income and other uses. Furthermore, policies to reduce deforestation will require involvement from all levels of government (e.g. federal, provincial and municipal) given the widespread but scattered occurrence of deforestation on both public and private lands, and the range of policies and regulations that could encourage or restrict deforestation practices. In order to illustrate the complex policy environment and multiplicity of deforestation activities, a range of possible policies are described in Table 4.4.5 to target the major sectors where deforestation is occurring.

Negotiation outcomes, particularly regarding the definition and interpretation of deforestation, will be critical in determining which types of deforestation activities will be counted as a source of CO_2 emissions. Which components of carbon stock releases will be counted, such as above and below-ground biomass, will also be important. The need to verify and monitor changes in carbon stocks from deforestation activities will require additional scientific tools and measurement systems, depending on the type and extent of deforestation activity. Deforestation which occurs predominantly on private lands such as forest conversion for agriculture, for example, will present additional barriers due to the geographic diversity of land-clearing activities.

If clearing for forestry access roads and infrastructure falls under the definition of deforestation then various measures could be taken to minimize debits. Various stakeholders suggested options such as increased horse-logging or helicopter logging, but the economic and environmental consequences of this type of response would need to be closely examined. In general, it is to be expected that main access road development for the forest sector will decline over time, as more second growth forest is harvested. Specific measures that could be considered for reducing the impact of forest access road building include:

a) reducing the volume of timber harvested (with significant negative impacts on employment and mill viability);
b) reducing the length of roads constructed per unit of timber harvested by increasing the scale of clearcutting to maximize road-building efficiency (with negative impacts to biodiversity, water protection and/or aesthetics);
c) reducing the dependence on logging in unroaded areas by substituting fibre from afforested or other intensively managed areas (with practical problems relating to transportation distance and tenure); and
d) speedy green-up of secondary roads, landings and skid trails (which is presumed in the estimates shown in Table 4.2.2).

Policies to reduce deforestation for agriculture will need to be balanced against other economic and social objectives (e.g. regional economic development and rural employment), due to the importance of agriculture to many rural communities. Also, since most clearing of forests for agriculture and rangeland development likely occurs on private land, policies to reduce deforestation will require the co-operation and involvement of relevant provincial governments and individual land owners. A range of policy options would likely need to be evaluated in order to identify the most cost-effective mix of voluntary and/or non-voluntary measures to reduce deforestation on private land, recognizing the complex range of existing agricultural policies and regulations.

Table 4.4.5
Sample Policies to Reduce Deforestation

Target Source	Types of Policies	Key Stakeholders and/or Public Concerns
Land use change categories		
Agricultural land clearing	Taxation incentives for forest protection; compensation payments/conservation covenants; forest clearing planning controls; education and promotion policies.	Reduced returns and lower competitiveness of agricultural sector. May adversely affect some agricultural regions more than others (e.g. Western provinces). Monitoring and reporting costs likely to be high.
Mining and petroleum development	Codes of mining practice and regulations to minimize forest clearing; environmental performance bonds; taxation incentives/financial assistance schemes to promote best environmental practice.	Reduced returns and lower competitiveness of mining sector. Regulatory approach likely to increase exploration and mine costs.
Electricity generation	Environmental planning controls/regulations to minimize deforestation at a project level; including off-site requirements (e.g. compensatory planting requirements).	Increased costs of electricity.
Urban/residential development and recreation	Forest clearing regulations; environmental performance bonds; taxation/financial assistance schemes to reduce forest removals at a project level.	Likely to increase cost of local developments such as housing and recreation (e.g. ski resorts, golf courses). Will involve co-operation and partnerships with provincial and municipal governments. May reduce taxation base of municipal governments through lower investment.
Non-land use change categories (e.g. partial removal of crown cover)		
Forestry access roads and infrastructure	Codes of forest practice/guidelines to minimize tree removals for forestry infrastructure and accelerate restoration of disturbed sites; off-site programs such as afforestation and use of other intensively managed forests to reduce reliance on unroaded areas for timber supply.	Considered part of normal forestry operations and not deforestation. Likely to restrict ability to access large undeveloped areas across Canada, particularly in British Columbia. Off-site programs unlikely to offset reliance on presently unroaded areas, at least in the medium term.

A study for the Forest Sector and Sinks Tables to investigate whether current land-use or agricultural policies were encouraging deforestation concluded that deforestation for agricultural purposes was limited and tended to be on the decline, and that there was little evidence to suggest that it would increase under current economic and policy conditions. It also concluded that the major factor affecting agricultural clearing was the private landowner's assessment of the relative profitability of land use in forestry versus agriculture, and that the lands which would be most profitable for agricultural use have already been converted to agriculture. Government financial support for agriculture has declined in recent years, reducing incentives for land conversion.

It is important to note that any level of deforestation in the commitment period will increase the challenge in meeting Canada's Kyoto commitment, even if the rate of deforestation is declining over time. This is because CO_2 emissions from deforestation are not included in the 1990 baseline, but the emissions from deforestation in the commitment period are added to the emissions from fossil fuels to determine compliance with the target, and will increase the mitigation effort required to meet the target. Even a small amount of deforestation can be significant, as the debits are relatively "instantaneous", and cannot easily be offset by credits due to afforestation or reforestation.

A possible perverse effect of deforestation policies may be to accelerate some types of deforestation activities prior to the first commitment period. The potential for a perverse environmental effect is largely due to the accounting methodology required by the Kyoto Protocol, which refers to verifiable changes in carbon stocks within the first commitment period (i.e. between 1 January 2008 and 31 December 2012), including changes in carbon stocks from deforestation activities. A possible consequence of these accounting rules is that deforestation which occurs prior to 2008, such as in 2001, may not be counted and hence provides an incentive to undertake deforestation activities prior to the first commitment period. Possible mitigating factors against this perverse effect include existing environmental and land management legislation and policies, and the design of possible domestic policies to recognize credit for early action that reduces deforestation.

In addition, the dynamics of carbon stock changes may still result in some emissions from deforestation activities which occur prior to 2008 being counted. This is largely due to the lagged effect of emissions from some carbon pools such as soils, humus and coarse woody debris, which may result in an increase in CO_2 emissions for several years after the initial deforestation disturbance.

Further Analytical/Study Needs

While the studies carried out by the Forest Sector and Sinks Tables have advanced our knowledge of deforestation, there is still a high degree of uncertainty related to the estimates. Information on the areal extent, spatial location, carbon release, and causes of deforestation remains limited and is a critical information gap. Deforestation estimates may be improved through further research, such as using remote-sensing technologies combined with statistical surveys. Further research into the design and implementation of effective policies to reduce deforestation is also needed, given the large range of activities and sources from different sectors which currently contribute to deforestation in Canada. However, the key data and definitional uncertainties need to be resolved.

4.5 NOT CURRENTLY IN PROTOCOL: THE MANAGED FOREST AND CARBON STORED IN FOREST PRODUCTS

Under Article 3.4 of the Protocol, there is provision for negotiation on additional human-induced activities resulting in emissions from sources and uptake by sinks in forests. These activities would be added to those already permitted by the Protocol in the second and subsequent commitment periods, as well as in the first commitment period if the Party so chooses. As a result, various activities have been proposed that could enhance carbon sinks in forests. These include specific forest management activities such as thinning, fertilization and fire protection. The advantage of this approach is that it would enable recognition of incremental activities that increase carbon storage, even if Canada's managed forest is determined to be a source. However, some Table members feel that increasing the number of activities accepted under the Protocol would further complicate the methodology for accounting for verifiable changes in carbon stocks that could be attributed to these specific activities.

An alternative approach is to include all management activities within a specified area, such as the managed forest, and to conduct a full accounting of changes in carbon stocks within that area, including the impact of various forest management practices. This would be more consistent with sustainable forest management objectives being pursued by many countries including Canada, and is more complete in its treatment of sinks and sources than the current piecemeal approach of the RAD. This section does not consider the option of adding specific individual forest management activities to the Protocol, but discusses these activities within the context of the managed forest approach.

Issues related to accounting for other activities will be addressed in the IPCC Special Report on Land-Use, Land-Use Change and Forestry, due in the early summer of 2000, and decisions may be taken on Article 3.4 at COP6 in the fall of 2000. As such, it is important that Canada determine as soon as possible the net impact on its carbon balance of each negotiating option and determine which option it should promote in international negotiations.

A related but separate issue is the accounting for carbon stored in forest products. If a managed forest approach is adopted, then changes in carbon stocks due to harvesting activities will need to be accounted for. For a proper accounting of carbon stocks, the storage and subsequent decay of carbon in forest products is critical. Currently, IPCC guidelines assume that once a tree is cut, emissions occur immediately in that year. This is a gross oversimplification, as some biomass will decay on site, some will decay in landfill a little later, and some will remain stored for years as, for example, framing for houses. A number of options discussed in this section will only benefit Canada if the carbon storage in products is properly accounted for. In other cases, the proper accounting of products increases the benefit (or reduces the debit) from activities. There may also be an opportunity for modifying product mix decisions to reflect carbon storage impacts, although this would need to be balanced against many other objectives. In addition to accounting for the carbon stored in forest products, the issue of who "owns" the credits for exported products is obviously an important one for Canada.

Countries recognize the inadequacy of the current IPCC guidelines and have proposed alternative methodologies that have yet to be agreed to. As well, it is not yet clear whether or not the current IPCC guidelines will in fact apply to the accounting under the Kyoto Protocol, or whether new guidelines will be developed.

Clearly there is a biological limit to the increases in carbon stock that can result from changes in forest management practices or forest products strategies relative to current practices. Sooner or later the carbon stocks of the managed forest and the forest product stocks will reach equilibrium and remain constant over time, assuming sustainable forest management practices and continued forest harvesting and protection. At this point, the carbon reservoir (in total metric tons of CO_2) may have been "permanently" increased but the sink (in Mt CO_2/year) is zero (i.e., sinks and sources are balanced). As such, the benefits of forest carbon sinks as measured by changes in the managed forest are not a "permanent solution" to emission reductions, but can provide a useful temporary measure, as changes in forest management enhance the amount of carbon sequestered over a period of time.

The work by Schlamadinger *et al.*(1997) with the GORCAM model provides some useful insight, bearing in mind that the model is calibrated to US conditions and models individual forest stands rather than the forest as a whole. The GORCAM model tracks all of the carbon stocks and flows impacted by forest management decisions, and includes storage of carbon in forest products, as well as fossil fuel use in harvesting, production of wood products and other substitute construction materials. The model shows that "although there can be significant storage of C in trees, soils, forest litter, and forest products, all of these C pools reach equilibrium over time and then provide no further C sequestration." Over the long term, the main contributions of the sector come from the use of biomass fuels to displace direct fossil fuel-uses and the savings of fossil fuels used to make product from energy intensive materials by using wood products instead. This is because, while "the C physically sequestered in the wood remains sequestered only for the lifetime of the product, the CO_2 emissions avoided by not using fossil fuels are avoided forever." These results are for a hypothetical forest and there are many differences between that and a real forest. The transitional effects of practices may be important in an actual forest. The use of biomass for energy and the potential for reducing fossil fuel use through the substitution of energy intensive products with wood products are discussed separately in Chapters 2 and 3.

4.5.1 Analytical Issues and Uncertainties

The Managed Forest

The managed forest approach means that all management activities within the managed forest are included and a full accounting of changes in carbon stocks is conducted within that area. This approach is consistent with encouraging the maintenance and enhancement of carbon sinks and reservoirs, which is an objective of the Framework Convention on Climate Change. It is more balanced in considering both removals from sinks and emissions from sources than the current provisions of the Kyoto Protocol (i.e., RAD). In addition, it is more consistent with sustainable forest management objectives being pursued by many countries including Canada, and also appears to be more practical from a measurement and verification point of view.

Key uncertainties relating to a managed forest approach:

- components of carbon stock
- definition and extent of managed forest
- emissions from man-caused and/or natural fires in or out
- accounting rules (for determining offsets to target)
- accounting for storage in forest products and how
- measurement and verification methodologies (ground measurement versus modelling)

The implications of a managed forest approach will vary by country, depending upon the age class structure of their inventory, extent of management for timber and other objectives, and growth rate of trees, among other factors. Carbon stocks on a country's managed forest may be increasing, decreasing or remain constant over time under current management regimes. For example, the US has had increasing carbon stocks on its managed forest since 1990 due to both an increasing area of forest as well as increases in growing stock on that forest.

From Canada's point of view, the managed forest approach raises a number of questions that have yet to be resolved. This includes, for example, the definition of the managed forest in Canada. Current estimates range from 120 million ha to 235 million ha, depending upon one's definition, compared to the total area of forest in Canada of roughly 417 million ha. Some have argued that a large portion of this area should be considered managed because a conscious decision has been made to "not protect" the forest. However, Canada is different from most countries in that we have a forest industry that operates mainly in the natural forest under extensive (as opposed to intensive) management. Even second growth stands tend to be relatively un-managed. The area of so-called managed forest in Canada is in fact likely to change over time, for example as product prices and changes in technology make areas economically accessible, and as environmental and conservation forces cause areas to be set aside for other uses.

Canada also has a very high natural disturbance regime compared to most countries. The Framework Convention on Climate Change, and the Kyoto Protocol to the Convention, focus on anthropogenic emissions only. As such, emissions from natural disturbances are not currently considered part of Canada's emission target. But it is unclear how CO_2 emissions from forest fires would be handled if the Protocol moved to a managed forest approach. It is estimated that Canada's forests as a whole (i.e., not just the managed forests) are currently a net source of CO_2, on the order of 69 Mt C per year, predominantly as a result of fire disturbance as noted earlier. Taking into account conversion of some of this carbon to forest products, net average annual emissions from the total forest are estimated to be about 45 Mt/yr or 165 Mt of CO2 -equivalent (Kurz and Apps, 1999).

In addition, there is the uncertainty already mentioned about which and how many components of carbon stock will be considered under the Protocol (i.e, above ground biomass, below ground biomass, soil carbon). If the managed forest was included under the Protocol instead of (or in addition to) RAD, the carbon stored in forest products would need to be considered as well, since harvesting and production of products would be one of the key activities on the managed forest. We assume here that RAD would be a component of the managed forest, i.e., areas afforested would become part of the managed forest, deforestation would count as a debit, and reforestation (however defined) would also form part of the managed forest. In fact, if reforestation is defined as regeneration after harvest, then over a period of 100 years or so, the "Kyoto forest" will in fact equal the "managed forest" in Canada.

It should be noted that Article 3.4 of the Protocol states that parties will decide..." modalities, rules and guidelines as to how and which additional human-induced activities related to changes in ghg emissions and removals in the agricultural soils and land use change and forestry categories, shall be added to, or subtracted from, the assigned amount for Parties..." This means that rules for adding additional activities and how they should be accounted for remain highly uncertain - it is not even clear that the accounting would be done using changes in carbon stocks in the commitment period, although that is what we are assuming for simplicity and for consistency with Article 3.3. Another, perhaps more likely, alternative would be a net-net approach. In other words, the net removals (i.e., removals by sinks minus emissions from sources) from the managed forest in 1990 would be added to a country's 1990 baseline, and the net removals from the managed forest in the first commitment period would be added to a country's target. The country would obtain a net benefit for the commitment period if net removals had increased from 1990, and a net debit if they had decreased.

Because of these uncertainties, it is difficult to estimate the BAU net removals in Canada under a managed forest approach. Preliminary work is underway using the Carbon Budget Model (CBM-CFS2), however this will provide only rough estimates under alternative scenarios, and much remains to be done in terms of modifying the model and improving the base data in order to come up with realistic estimates of carbon stock changes on the managed forest.

One possible definition of the managed forest is the 138 million ha included in the accessible non-reserved stocked timber-productive forest. Using IPCC measurement guidelines, which are concerned only with anthropogenic emissions, Sellers and Wellisch (1998) estimated that this area was a net sink of 45 Mt CO_2-equivalent in 1990, currently is a sink of about 30 Mt and will be a sink of about 10 Mt in 2010 (see Table 4.5.1). These results are based on the calculation methodology in the IPCC 1996 Revised Guidelines - other methodologies result in different results. As shown earlier, the entire Canadian forest was estimated to be a net source of 45 Mt/yr in 1990. The results in Table 4.5.1 exclude emissions from wildfires on the managed forest, as the long run impact of fires is assumed to be included as part of the average standing volume per hectare. In addition, net emissions/removals from the overmature ageclass of the managed forest are assumed to be zero. Deforestation is also excluded. Care must be taken in using and interpreting this estimate as many assumptions had to be made. In addition, IPCC guidelines may be revised or new guidelines written, as noted earlier.

Table 4.5.1
1990 Emissions (+) and Removals (-) on the Managed Forest Under Current IPCC Guidelines

	Mt CO_2 / y
Growth	-290
Harvest*	176
Slash	69
Net removals	**-45**

* Assumes immediate emissions in the year of harvest.

Industry representatives have long claimed that the growth of second growth forests in Canada is much higher than previously thought, and that estimates of average growth based on existing forests will underestimate the actual growth that is occurring on the managed forest. On the other hand, the total volume of carbon per hectare (i.e., the reservoir) is in general higher in primary forests, although there are some regional exceptions. These forests are likely to be considered part of the managed forest at the time of their first harvest, resulting in an initial reduction of carbon stock that may never be fully compensated for by subsequent regeneration, even though the productivity of second growth forests, in net carbon per ha per year, may be much higher. The lack of large-scale nationally accepted growth and yield information creates a problem for estimating potential gains from the managed forest under the Protocol. This information would also likely be needed in order to provide estimates of verifiable changes in stock within the commitment period, since "verifiable changes" will likely need to be estimated in part from models and not just actual ground measurements.

One further outstanding issue related to the negotiations needs to be resolved in order to determine the potential contribution of the managed forest for Canada. This is how CO_2 emissions from biomass energy would be considered within the Protocol. Currently energy from biomass is considered to be CO_2 neutral. Much of the historic reduction in direct CO_2 emissions in the pulp and paper industry, and proposals for further reductions, are based on increased fuel-switching to biomass for energy from fossil fuels. The reason that biomass energy is considered to be CO_2 neutral is that it is assumed to come from a sustainable forest resource. Under a managed forest approach, a full accounting of carbon flows

including forest products and biomass as fuel would take place, so that while the biomass energy would still offset fossil fuel use, there would likely be a requirement to track the CO_2 emissions. Thus the impact for Canada of using the managed forest approach cannot be assessed without taking into account the industry implications.

As noted earlier, decisions related to negotiations will likely not be forthcoming until fall of 2000 or later. However, it important to consider the potential benefits of a modification to the Protocol that would look at changes in stocks on the managed forest, and to consider the types of options that could be implemented to increase carbon stocks under such an outcome. There are various ways to increase carbon stocks in the managed forest that generally relate to: increasing growth rates (i.e., productivity), increasing rotation length, and increasing the maximum volume attainable on a site. There are complex interactions between these various factors, and increasing one while maintaining the others constant will increase carbon stocks, but increasing one at the expense of one or both of the others will not necessarily result in a net carbon benefit. In addition, it is important to consider the time dimension - in some cases, strategies may merely move the carbon through time with no overall net benefit, although this may be of interest from the point of view of obtaining credit for carbon earlier.

There has some research on the impacts of alternative management practices to increase carbon stocks on forest lands. Most management activities have been studied from the point of view of impacts on merchantable volume - not total site biomass. What is clear from a review of this work is that the impact of various management strategies (e.g., thinning, spacing, fertilization, etc.) is species and site-specific and there is no one strategy that will fit all forest types and all regions (or countries). This makes it difficult to estimate the potential impact of putting in place policies that would facilitate these management practices. In some countries and regions, these management strategies are economic and are already used in order to increase wood supply - however, they are not currently used to a large extent in Canada.

Carbon storage in forest products

There are significant amounts of carbon stored for long periods of time in forest products. Paper, wood and other forest products contain carbon that was initially absorbed by the tree. Carbon is stored in forest products for varying periods of time depending upon its end use, before it decays and releases carbon back into the atmosphere. Depending upon the product produced, the carbon could be released very quickly or very slowly back into the atmosphere. For example, some wood and paper products such as historical buildings, and books in libraries are expected to lock in carbon for longer periods of time than office paper products and wood pallets (see Table 4.5.2). Currently, IPCC guidelines assume that once a tree is cut, emissions occur immediately in that year, which is actual fact only true for a small proportion of the carbon in the tree.

Table 4.5.2
Average Half-Lives of Carbon in Paper and Wood Products

End Use	Half-Life of Carbon* (years)
Single-family homes (pre-1980)	80
Single-family homes (post-1980)	100
Multi-family homes	70
Mobile homes	20
Nonresidential construction	67
Pallets	6
Manufacturing	12
Furniture	30
Railroad ties	30
Paper (free sheet)	6
Paper (all other)	1

* Half-life is the time after which half the carbon placed in use is no longer in use.

Source: Skog and Nicholson (1998).

Converting mature forests into solid wood products locks in the CO_2 and prevents its release into the atmosphere. The carbon is released once the forest product has reached the end of its life-cycle (i.e., begins to degrade) or is disposed as waste in a landfill or is burned (see Table 4.5.2). This process is part of the larger carbon cycle. The patterns of landfill decay are much different for wood than paper. Very little decay occurs to wood while in landfills so that the proportion of solid wood converted into CO_2 is very small (about 3 percent) even after very long time periods. Paper and newsprint, on the other hand, is subject to higher levels of decay resulting in a larger proportion converted into CO_2 (16 to 38 percent).

Of course not all wood that is harvested is converted into forest products. Some is left on site as slash and some is turned into waste onsite at the mill, although much of this mill waste is either made into other products (e.g., chips into paper) or burned for energy (e.g., bark), although some is landfilled. Proper accounting of these by-products is also required for a full accounting of carbon flows.

Whether the forest products carbon pool is growing (a sink) or shrinking (a net source) depends upon whether the amount of carbon harvested and processed into products is greater than the amount emitted in manufacture plus the decay of older products. If harvesting is increasing, the amount of carbon stored in the products pool grows quickly; if harvesting is relatively constant (like today) the products pool grows more slowly - but it still grows. The average annual growth in the products pool (new products minus manufacturing losses minus decay) from Canadian forests is 22.7 million tonnes of carbon (83.2 Mt CO_2). However, 17.4 Mt is exported to the US and only 5.6 Mt stays in Canada. Possibilities to increase carbon storage in forest products include promoting longer use of forest products through recovery, recycling and reuse, and changing the focus of production to products with longer lifespans (eg. less newsprint, more lumber). Whether Canada would obtain a benefit or not from expanding forest product carbon pools would depend upon the measurement and accounting systems used. An important issue here, particularly given the Canadian industry's reliance on export markets, is who would receive the credit for the storage of carbon in products, and any debit for the eventual emissions - the importer or exporter.

4.5.2 Modifying Forest Management Practices to Increase Carbon Sequestration on the Managed Forest

There are a number of potential actions that could increase the net carbon stock of the managed forest, and therefore increase the net potential contribution of the managed forest to Canada's emission reduction target, **assuming that the negotiations result in a requirement to report and use as a potential offset the changes in stock on the managed forest in the commitment period.** Clearly, any changes to current practices should be done in the context of sustainable forest management, and should not promote carbon sequestration at the expense of other environmental or sustainable development objectives. It is also clear that practices which increase CO_2 sequestration may or may not be the same as those that increase merchantable timber supply volume for industrial use.

Forest management strategies which have been proposed for increasing carbon sequestration include:

- reducing the regeneration delay after natural disturbances or harvest through planting or seeding
- restoration of degraded sites and NSR (not sufficiently restocked) lands
- use of genetically enhanced trees
- fertilization
- control of pests and diseases
- increased protection from fire
- commercial thinning
- juvenile spacing
- increasing rotation age
- changing species mix (e.g., planting fast-growing short-rotation hybrid species)
- reducing harvest levels (i.e., set-asides)
- changing harvest methods.

Some forest management strategies, such as commercial thinning and juvenile spacing, may maintain or reduce the on-site carbon immediately after the activity, and provide their major benefit after harvest, by increasing the carbon stored in forest products or by allowing some stands to remain that otherwise would have been harvested. While planting and use of genetically enhanced trees will directly increase carbon stocks in the first few commitment periods and beyond, the carbon benefits from thinning and juvenile spacing can only be achieved over a rotation (i.e., 40 to 60 years). In order to obtain benefits in the first and subsequent commitment periods, accounting rules that allow for the amortization of benefits over the rotation or the incorporation of credit for carbon storage of forest products, may be needed.

Intensive forest management practices will tend to increase the average productivity of the forest (i.e., in m^3/ha/year). The total impact on forest level standing carbon stocks is difficult to conceptualize, because of the transitional effects over time. Among other things, these transitional impacts are dependent upon the age class distribution of the forest, the age at which the treatment is applied, how long the impact of the treatment is, and whether or not there is an allowable cut effect that permits an increase in harvest immediately after an investment in silviculture is made. However, the overall result of most of these intensive forest management activities will tend to be a one-time increase in standing carbon stocks on the managed forest as a result of increases in productivity, even if in the long term there is an increase in harvest equal to the increase in growth.
The carbon-sequestering potential of specific forest management activities has been estimated by the Canadian Pulp and Paper Association (CPPA, 1998), considering only the carbon in above-ground forest biomass. Most estimates of carbon sequestration benefits are based on preliminary calculations of commercial (i.e., merchantable) forest volumes and often fail to account for the impacts of the activities on all ecosystem carbon pools. More in-depth scientific study is required to confirm the carbon impact considering all carbon pools, including soils. Few studies have assessed the economic implications of forest management activities for incremental CO_2 sequestration.

Reducing Regeneration Lag and Restoration of Degraded Sites

Planting to regenerate a forest after harvest, instead of (or in addition to) aerial seeding or natural regeneration, accelerates the process of stand establishment and permits the capture of carbon gains developed through tree improvement programs. Planting or other site preparation after natural disturbance can also reduce the regeneration lag for re-establishment, although consideration of other values such as biodiversity and aesthetics, as well as costs, need to be considered carefully. The rule of thumb is that planting provides a 10 year advantage over natural regeneration. No estimates of potential have been made at this time. Currently, about 45% of harvested areas are planted in Canada. See also the discussion in section 4.3.2.

There is also the potential to rehabilitate or restore degraded sites, or areas that have not previously regenerated successfully after harvest (i.e., NSR lands). These areas are still considered part of the managed forest. Many of these areas have regenerated to non-commercial tree species and shrubs, so that an assessment would be needed to ensure that net carbon sequestration was increased.

Genetic Tree Improvement

Genetic tree improvement is a term for developing, producing and planting faster growing stock, usually through a process of tree selection and production of superior planting stock. Genetic tree improvement programs can increase the rate of growth, as well as pest and disease resilience of seedlings produced for planting programs. If growth was increased by 15% through the use of genetically enhanced stock on all areas planted/seeded since 2000, the sink capacity in the first commitment period would be approximately 0.5 Mt CO_2, but would increase substantially over time. The analysis by the CPPA shows a much higher benefit of 2 Mt of CO_2/year in 2008-2012 although they assumed that only 50% of all planting will employ enhanced seedlings. This higher estimate reflects an assumption of much higher growth rates for young trees.

Fertilization

Fertilization has been shown to provide a significant increase in growth if applied 10 to 15 years before final harvest on some sites. A net carbon budget needs to be determined to see if the increase in carbon sequestered more than offsets the carbon used to produce and apply the fertilizer. Opinions on this vary in the literature. The long term impacts of fertilization on total site biomass have also not been studied (i.e., understory, root biomass, soil carbon etc).

Pest and Disease Control

Pests and disease account for wood volume losses on the order of 61 million m^3 per year, compared to 170 million m^3 for harvesting and 88 million m^3 for fires. Some pests and diseases can be controlled or reduced by spraying biological or chemical pesticides, but application of pesticides has declined in recent years due to environmental and health concerns. Reducing damage from pests or disease allows the mortality to be "captured" so that the forest is harvested and the carbon stored in forest products, and it can also mean that another forested area was not harvested. The CPPA estimates that this is one of the cheapest options for increasing carbon stocks on the managed forest, and that an estimated 6 Mt/year (or one third of the annual volume loss) could be saved by large-scale spray programs, at a cost of $0.75/ton of CO_2. This figure is based on an assumption that the carbon credit would be equal to the volume of the trees that have been 'saved', and does not consider the implications of repeated spray applications on a particular site over the life of the trees. Besides the environmental and health concerns, there is a great deal of uncertainty about the long run impact of spraying on pest populations and the biomass accumulation impacts including the impacts on understory vegetation and endemic levels of the insect or disease being sprayed for as well as other insects and diseases.

It is clear, however, that under a managed forest approach where changes in carbon stocks are used to offset Canada's target, the issue of enhanced protection of forests to avoid significant pest and disease losses will need to be examined from a strategic perspective. Reducing mortality and losses from natural disturbance may, in some areas, be a cost-effective option. However, substantially more work and more information is needed on this topic before options can be recommended.

Modified Fire Control

Natural disturbances, such as fire and insects, play an important ecological role in the dynamics of Canada's forests and have a huge impact on biomass accumulation and emissions. It should be emphasized, however, that the Framework Convention on Climate Change, and the Kyoto Protocol to the Convention, focus on anthropogenic emissions only. As such, emissions from natural disturbances are not considered part of Canada's emission target. However, if the managed forest approach is adopted, it is likely that Canada would be responsible for emissions from fires on the managed forest, whether naturally caused or caused by humans.. Some have argued that we should attempt to obtain credit for the fire control that we already carry out - in other words, we should seek carbon credit for "saving" the forest from being burned. Consultations with forest fire experts clearly indicated that this was a risky proposition. While fire management strategies will need to be re-examined under a managed forest approach, initial analysis also indicated that the scope for cost-effective reductions in fire disturbance in order to protect carbon stocks is probably limited.

There are two zones of fire protection in Canada: the observation zone (i.e., areas of extensive or modified suppression where fires are monitored but not actively suppressed unless values are at risk) and the intensive protection zone. The intensive protection zone is consistent with one might call the "managed forest" but there is not a one-to-one correspondence. In most years, the vast majority of the area burned (on average 65%) occurs in the observation zone.

Fire is a natural disturbance in Canada's forest, essential to ecosystem maintenance and productivity through its influence on landscape diversity and biogeochemical cycles, including the carbon cycle. Fire management agencies have long recognized that excluding fire is neither ecologically desirable nor economically feasible. The generally-practiced policy of modified suppression in observation zones is a reflection of this awareness. Opportunities to sequester more carbon through more intensive protection in current observation zones are not likely to be viable for the following reasons:

i fire is natural in Canadian forests and global biodiversity concerns dictate that a certain amount of fire be maintained in these ecosystems;

ii forests in these zones are largely unmerchantable, particularly when the cost of access and wood extraction is considered;

iii fire protection in these remote regions would be extremely costly (infrastructure establishment and maintenance) and likely much less effective due to longer detection and response times; and

iv current climate change scenarios indicate increasingly severe fire weather conditions, more frequent and extreme fire activity (particularly lightning fires), and significant changes in forest structure and carbon storage in northern Canada, making the effectiveness and carbon benefits of increased protection efforts highly uncertain.

Forests in the intensive protection forest zone are used for both industrial and recreational purposes, and fire management agencies actively suppress fires to ensure the protection of human life and property, as well as a continuous timber supply from economically valuable industrial forests. This zone includes all of BC, Alberta and the Atlantic provinces, and the southern and central regions of Saskatchewan, Manitoba, Ontario and Quebec. The vast majority of fire management resources are focussed on intensive protection of these assets, and fire management agencies are generally successful in reducing fire impacts in these regions. There are a number of reasons why it may not be possible to effectively further increase protection in these forests.

Fire cannot be eliminated, as extreme fire weather conditions often create unmanageable situations (e.g., multiple ignitions and intense fire behaviour) and fires escape initial attack. Once fires escape, the effectiveness of further and more costly suppression activities is severely compromised, and many fires run their course. As well, agencies do not budget for extreme situations, as these are intermittent, and would require infrastructure costs that would be unwarranted most of the time. The law of diminishing returns applies here, and increased expenditures do not guarantee increased success.

Seeking credit for successful protection is an extremely risky undertaking in countries like Canada and Russia with large forest resources. Fire impacts are highly variable from year-to-year, and accepting responsibility for protection means running the risk of major carbon debits in significant fire years, something likely to become more common under projected levels of climate change. Given these and other carbon accounting issues, it must be anticipated that protection is not likely to be considered as an additional forestry activity under the Protocol. However, under a managed forest approach, countries may be responsible for emissions from wildfires on their managed forest. In this case, a careful review and further analysis of the costs and benefits of increased fire protection on the managed forest would need to be considered.

Commercial Thinning

Commercial thinning is the harvesting of a portion of a stand before it reaches rotation (normal harvest) age. Thinning involves the removal of trees that would normally be lost to mortality at an intermediate stage in the growth of the stand. Thinning does not result in a greater amount of standing biomass at rotation age, but it results in a higher yield over the rotation period, because of utilizing both the thinnings and the final harvest. The thinning volume removed is converted into products, thus storing the carbon in potentially long-term storage such as lumber and other wood products. Commercial thinning also offers the benefit of extending wood supply, in the sense that a higher volume per hectare can be achieved from a hectare over the rotation, thus leaving uncut other stands that might otherwise have been harvested.

While current rates of commercial thinning are very low in Canada, increased commercial thinning to 200,000 ha per year could sequester an additional 26 million tonnes of CO_2 over one rotation according to preliminary estimates by the CPPA based on two species only. Because we are assuming that a managed forest approach would be measured based on changes in stock in the commitment period, this carbon benefit would likely only be a positive benefit if the carbon stored in forest products (i.e., from the thinnings) counted as carbon stocks, or if the wood from commercial thinnings reduced harvest activities elsewhere. An added benefit from efforts or incentives to increase commercial thinning would be the potential reduction in use of clearcuts in some areas.

Further work is needed to assess whether the increased thinning activities would result in reduced input of coarse woody debris into the dead organic matter pools of the ecosystem. One silvicultural objective of thinning is to capture the biomass that would otherwise be lost through tree mortality. In achieving this objective, less biomass carbon will be added to dead organic matter pools and these pools will therefore contain less carbon in thinned than in un-thinned stands. If the reporting guidelines for the Kyoto Protocol include both biomass and dead organic matter pools, then the net benefit of thinning will be lower than if only the biomass pools are assessed. And if carbon stored in wood products is not included in the Protocol, then thinning may not be a beneficial activity from the point of view of carbon.

Juvenile Spacing

Juvenile spacing is the thinning of dense juvenile stands (10-20 years old) to ensure that all trees have enough room to grow and develop at optimum rates. It is often useful for adjusting species mix to help achieve biodiversity, sustainable practices and other management goals. Spacing tends to increase the average diameter of stems and achieve higher merchantable volumes, but not necessary increased biomass at rotation age. Producing higher levels of merchantable volumes may also increase carbon stocks if carbon in forest products is included, e.g. if more lumber can be produced. However, juvenile spacing can also reduce rotation age, allowing harvesting to take place at a younger age and can also increase growth in forests that are stagnating from high levels of competition.

The CPPA estimates that current rates of juvenile spacing are 375,000 ha/year. This will increase carbon sequestered by increasing the yield of forest products from a given area over time by 50%, e.g., over the same time period, there are three rotations instead of two on the same area. In other words, these 375,000 ha/year will produce the same amount of forest products as 560,000 ha/ year of un-spaced sites do today. At an average of 240 tonnes of CO_2/ha at rotation, this is a savings of 44 megatonnes of CO_2 (240 tonnes/ha x 185,000 ha /yr). Alternatively this can be viewed as an increase on average of 1.6 t/ha/year over approximately 150 years. This means that carbon stocks will increase overall if credit is given for forest products carbon storage, or if the harvested area of the managed forest is reduced overall (i.e., the increase in harvest volume due to spacing is used to offset volumes from other areas). The above estimates are based on one species only.

Spacing programs are estimated to cost in the range of $4/tonne CO_2, by the CPPA but there are additional factors and benefits such as larger diameters and lower rotation age which might improve the cost/benefit profile of the activity for industry. In addition, regional variation in species and sites mean that the response to juvenile spacing varies widely across Canada.

Increasing Rotation Age

Increasing the rotation age of a stand will tend to increase the standing volume of the stand (assuming that the stand has not yet started to decline). Substitution of long rotations for short ones will increase the average volume of carbon sequestered in trees (assuming no change in disturbance regime etc). Again, it is not clear that total carbon on the site increases overall when other carbon stocks, such as understory, are included. Considered over the entire forest, a lengthening of rotation age on all stands might have an impact on the harvestable volume of the forest, although this would depend upon the age structure of the forest, harvesting methods, current rotation ages, etc. When CO_2 or other non-timber benefits have a positive value, then studies have shown that in fact the "optimal rotation age" lengthens compared to what it would otherwise be when only timber benefits are considered.

Reducing Harvest Levels

Reducing harvest levels and/or setting aside areas of protected forests for carbon sequestration or other purposes may or may not increase standing volumes and carbon stocks. The impact is likely to be greatest if harvesting is reduced in regions where natural forest succession and growth results in stands that are longer-lived or higher in volume than would be the case if the areas were harvested on a rotation cycle designed to maximize fibre flow. Again, the impact would depend upon such things as the interval between natural disturbances compared to the rotation age at which the stand would otherwise be harvested, the average age and the age distribution of the forest, the species, region etc., and the type of forest product produced after harvest. The economic cost of reducing harvest volumes could be significant (i.e., a high opportunity cost). In addition, if the area was to be protected, then there would be a protection cost. Over time, the forest would likely age and decline, with subsequent losses of forest carbon to the atmosphere, or, if the area was a mix of age classes, then a steady state would be achieved with no net losses or gains. Recent studies have also shown that reducing or delaying harvests may not have an impact on the carbon in the atmosphere, because of increased harvests elsewhere in the world. Increased use of more energy intensive product substitutes could also result in increased net emissions.

Summary of Impacts on Onsite and Offsite Carbon

Changes in forest management practices will impact both the on-site carbon (i.e., trees, vegetation etc.) and the off-site carbon (i.e., stored in forest products). It will also affect energy inputs - for example, increased use of planting for regeneration after harvest will tend to increase fossil fuel use compared to natural regeneration. Table 4.5.1 attempts to summarize the stand-level impacts for various groups of forest management practices, and highlights the complexities of this issue. Impacts vary depending upon the time-scale (short-term/long-term) and whether the increase in volume is used to displace harvests from other areas (i.e., the total harvest level is unchanged) or is used to augment the harvest level.

There are also important transitional impacts at the forest level that are not reflected in these stand-level impacts. The standing volume of the total forest overall may increase or decrease over time as a result of stand treatments but the effect will depend upon many interrelated factors such as age class distribution, species, etc. Stand level impacts are conceptually to understand easier than forest level impacts because of these transitional impacts.

Table 4.5.3
Summary of Stand-level Impacts on On-Site and Off-Site Carbon

Activity	Impacts on On-site Carbon		Impacts on Off-Site carbon		Impact on Energy Inputs	
	Trees Only	Above and Below Ground Biomass	Harvest Level Constant	Harvest Level Increased	Harvest Level Constant	Harvest Level Increased
Planting, genetic tree improvement, fertilization	short term positive, long term variable	unknown	neutral or positive (if can produce more long-lived products)	positive	increased	increased
Commercial thinning	short term negative, long term variable	unknown	neutral or positive (if can produce more long-lived products)	positive	neutral or increased	increased
Juvenile spacing	short term negative, long term neutral or positive	unknown	neutral or positive (if can produce more long-lived products)	positive (if can produce more long-lived products)	neutral increased	neutral increased
Pest and disease control, fire control	short term positive, long term unknown	unknown	neutral	positive	likely increased	increased
Increased rotation age, reduced harvest levels	positive if natural disturbance regime less frequent than harvesting cycle	unknown	negative (but may be neutral globally)		reduced, but indirectly may increase energy use if reduced harvest increases use of more-energy intensive products	

4.5.3 Modifying Forest Products to Increase Total Carbon Stocks

As noted earlier, there are actions that could be taken to specifically affect the carbon stocks of forest products. The benefit to Canada would depend upon whether carbon from forest products are considered part of carbon stocks for offsetting against the emissions targets, as well as the accounting/measurement system used to track carbon stocks (e.g., who gets credit for the carbon in exports of wood products).

Changing Product Mix

If carbon stored in forest products is included in the Kyoto Protocol, then strategies to modify the product mix in order to increase the length of time that carbon is stored before it returns to the atmosphere, could be implemented. These could include producing more long-lived products such as lumber as opposed to paper products. Obviously the markets would be need to assessed as well as the suitability of the trees. Although there is regional variation, currently most wood is processed by a sawmill first, with the residues going to pulp and paper mills, so the scope for this option appears limited.

Increased Recycling

Recycling of both wood and paper products slows the carbon cycle. Wood or paper which is re-used to produce further products is delayed from going to landfill or otherwise decomposing. It also replaces wood that would be harvested from the forest. However, before recommending increased recycling for the purposes of increasing carbon stocks, a complete carbon accounting of paper recycling in Canada is needed, since wastepaper often must be transported long distances in order to be recycled, which consumes fossil fuels.

4.5.4 Further Assessment of Managed Forests and Carbon in Forest Products

Impediments to Implementation and Policy Requirements

There are many factors that limit the more widespread use of the various forest management activities described above to increase carbon stocks on the managed forest or offsite. These include:

- uncertainty surrounding tenure security of public land for companies which are reluctant to invest in activities to increase future wood supply unless they know they will have the right to harvest the wood.
- costs (most activities are not currently economic on many sites)
- lack of official recognition of growth and yield benefits of these activities. Increasing growth rates through investments in silviculture do not currently translate into increases in allowable cuts.

In addition to these more general impediments, there are impediments that are specific to the carbon sequestering potential of these activities:

- exclusion of these activities under the Kyoto Protocol
- unresolved ownership carbon rights on public lands
- lack of definitive scientific estimates of carbon benefits
- uncertainties about tree growth rates and measurement requirements for reporting
- lack of knowledge about offset opportunities

The types of policies that could help address some of these general barriers include:

- government recognition of volume benefits of management actions and subsequent revision of annual allowable cuts (AAC effect).
- provincial settlement of land tenure issues for the long term, or agreement to offer compensation to companies that increase growth rates through silviculture treatments to enhance growth, yet lose the right to harvest it
- establishing lower stumpage rates for commercial thinning to offset higher costs compared to normal harvesting

Policies related to carbon credits include:

- negotiation of managed forest or additional forestry activities into article 3.4 of the Kyoto Protocol
- resolving carbon rights ownership on public lands
- incentives and policies to reduce costs
- research to better establish the carbon impact of activities across different sites, species and rotations through extensive analysis of existing data and development of comprehensive growth and yield data, including growth and yield data for second growth forests and managed stands
- creating a clearing house for carbon offsets, including those from forests

Clearly further work on policy needs will be required, as the basic information base on impacts is improved and as the negotiation outcomes become clearer.

Regional and Intra-Sectoral Implications

As noted earlier, the impact of these various changes in management practices will vary across regions depending upon species and site conditions. The main forest product-producing provinces are BC, Quebec, Ontario and Alberta, although forestry is also important economically in most other provinces.

Competitiveness, Economic and Social Implications

These various forest management activities will result in greater employment opportunities, contributions to stability and well-being of rural communities, increased forest growth and wood supply, and environmental benefits. Forest management activities can contribute to economic sustainability and job creation, through the employment of students and members of First Nations, especially in disadvantaged regions. These programs further support economic sustainability by maintaining or improving the wood supply for the wood products industries and therefore the viability of local sawmills and pulp mills. Increases in wood supply in general can provide an opportunity to increase the forest sector's contribution to the economy. The forest industry is by far the largest contributor to the country's balance of trade, and the largest industrial employer.

Many of these activities are likely cost-effective on a cost/tonne CO_2 basis. However, our knowledge of impacts on all carbon pools is limited, in particular the long term dynamics of the various pools. Many of these activities enhance the volume of standing wood and hence other values need to be considered (e.g., increases in stumpage paid to governments by companies resulting from increased harvests).

Environmental and Health Impacts

Modifying forest management methods to focus on increased CO_2 sequestration may result in a range of environmental costs and trade-offs with other forest management objectives. These potential trade-offs include biodiversity conservation and ecosystem management objectives (e.g. provision of stand structural diversity and habitat); aesthetic landscape and recreation planning; stream and water quality considerations; and long term regeneration objectives (e.g. use of native tree species to minimize biological risks and diseases). The precise nature and extent of these types of trade-offs is uncertain and is an important information gap. It should be noted that some of these activities will increase the use of fossil fuel (see Table 4.5.1), particularly if increases in volume are used to increase overall harvest levels. In addition, increases in harvesting will result in increased emissions from processing. Increases in biomass could increase the use of biomass energy, with positive net benefits relative to fossil fuel use. Increased production and use of wood products may provide an indirect environmental benefit if used to replace more energy-intensive building materials such as concrete.

There is some evidence that activities such as juvenile spacing can result in added soil nutrients where thinnings are cut and left to decay on-site. It can also result in suitable habitat for wildlife as shown in some studies - for example, high populations of spruce grouse and hares have been shown in previously spaced forests.

Extent of Use of Same or Similar Actions/Measures in Other Countries

The American Forest and Paper Association actively supports the inclusion of existing forests and forest products in carbon accounting for meeting Kyoto targets. This option is also supported by the International Forest Industry Round Table, consisting of Australia, Brazil, Canada, Chile, Finland, New Zealand, Norway, South Africa, Sweden and the USA. In March 1999, the Chafee Bill was tabled in the US Senate for discussion. This bill would give regulatory credit for voluntary action to reduce ghg emissions and also would recognize enhancements to carbon reservoirs as carbon credits.

Further Analytical/Study Needs

While a preliminary review of the literature showed a large number of studies on above-ground merchantable volume impacts for specific species and regional cases, further analytical work and basic data collection is needed in order to determine the impact of these various actions on all carbon pools, and to assess the impact for all species and sites across Canada. Difficulty in obtaining consultant bids on this topic reflected the general lack of expertise and information availability on this issue. Even determining the BAU estimates proved difficult, because those analysts with the potential tool for analysis were already fully engaged in other Table work or work related to the IPCC Special Report on Land-Use, Land-Use Change and Forestry. Further work will continue on modifying the CBM-CFS2 model and database to permit scenario analysis on the BAU estimates under the managed forest approach. However, much work remains to be done on the basic data collection, including growth rates of the second growth forest, analysis of carbon impacts of management interventions, and other environmental impacts. Analysis of net impacts taking into consideration fuel use for increased management activity is needed.

Relationship to Other Actions/Measures

Actions to increase carbon sequestration from reforestation are also applicable under a managed forest approach. Reducing deforestation on the managed forest is also clearly relevant. Areas that are afforested may be considered part of the managed forest. As well, timber from afforested areas could be used to offset reductions in the Allowable Annual Cut due to lengthening rotation age, avoiding harvesting in primary or high-volume forests or other carbon-related set-asides, although there would be significant logistical and legal obstacles to be overcome.

Stakeholder Views

Most Table members agreed that the managed forest approach made sense to pursue. There was concern expressed by many members (especially industry representatives) that insufficient analysis had been done in this area by the Table given the perceived high potential sequestration benefit of various actions under the managed forest approach.

There was some disagreement among members on the potential benefits of the various actions and policies proposed to enhance carbon stocks. In particular, some members suggested that a clear separation between actions that affected on- site carbon (carbon in trees, understory, soil) as opposed to off-site carbon (carbon stored in forest products) was needed.

All agreed that more analysis was needed on this approach, and that negotiations should proceed with caution until the net impacts for Canada are determined. However, industry members were particularly concerned that policy measures and incentives be put in place sooner rather than later, to encourage voluntary behavior to enhance carbon stocks, even without the 100% assurance that the managed forest approach would be adopted in the Protocol.

5.0 SUMMARY AND RECOMMENDATIONS

In this chapter we summarize the analysis of the preceding chapters and make four sets of recommendations:

- recommendations based on the actions/measures evaluated by the Table - these recommendations are divided into 4 categories;
- recommendations for general policy directions which we believe will ensure the forest sector can contribute to helping Canada achieve its Kyoto target;
- recommendations for further analysis on actions and measures which we identified but did not evaluate; and
- recommendations on key areas for further study as background to better understanding the potential for forest sector emission reductions and increases in carbon.

For reference, Table 5.1.1 shows direct and indirect ghg emissions (i.e. emissions from the production of purchased electricity) of pulp, paper, lumber and panelboard mills (see Section 3.1). A target reduction of 6% below their 1990 emission level corresponds to a decrease of 0.4 Mt CO_2e in direct emissions and 4.2 Mt CO_2e in total emissions from the projected level in 2010, or a reduction of 18%. In fact, it should be noted that for ghg emission inventory accounting, only the direct emissions are assigned to the forest sector. However, the various actions that were analyzed were aimed at reducing both direct and indirect ghg emissions.

Table 5.1.1
Forest Products Industry GHG Emissions, Mt CO_2e

	Direct	Indirect	Total
1990	13.8	6.3	20.1
2010 projection	13.4	9.7	23.1
2010 target (6% reduction below 1990 level)	13	5.9	18.9

Note: does not include emissions from certain small segments of the industry which account for roughly 5% of its energy use.

5.1 REVIEW OF ACTIONS/MEASURES

Tables were asked, where possible, to present recommendations on specific measures - combinations of actions and policies to achieve each specific action, where 'policy' refers to an effort by government to realize an action. Thus a 'measure' involves the application of a policy for the purposes of achieving one or more actions. Together, a set of measures is defined as an options package.

Given an action, the development of a measure is a two-stage process. First, it is necessary to determine what type and level of government or other stakeholder support might be needed to achieve an action target - i.e., what would be needed to make the action financially attractive to the private sector, given the estimate of net costs to the private sector? The second step is to decide what specific government program, tax policy, regulation, guideline or other vehicle will serve best to provide the government support needed, or will facilitate the involvement of other stakeholders. The Table's analysis went only as far as the first of the two steps, although in Chapters 3 and 4 various potential policy vehicles were discussed.

5.1.1 Summary of Measures Evaluated

We started this Report by presenting an Actions Matrix which listed a wide variety of forest sector actions that could contribute to Canada's emission reduction target in the first commitment period (see Chapter 1). A subset of these actions was chosen for detailed evaluation of emission reductions or carbon offsets, costs and requirements for policy support. Setting the priorities for which actions to evaluate was based on a balancing of a variety of considerations, including *a priori* estimates of the relative potential for a large ghg impact in the first commitment period and later, as well as low cost and degree of uncertainty. The subset of actions/measures analyzed is summarized in Table 5.1.2.

Table 5.1.2
Summary of Forest Sector Measures
(See text for explanation of the Table)

Measure and Category of Recommendation	Type of Measure	Cost Effectiveness 1997$ / t CO_2e Reduced or Offset (10% discount)		Direct and Indirect GHG Emission Reduction or Offset, 2010 Mt CO_2e		Estimated Incentive for Realization 1997$ million	Section in Report
CATEGORY 1 MEASURES							
1 Select high energy-efficiency auxiliary technology - pulp and paper mills	energy efficiency	-90.8		0.65		0	3.4.5
2 Improve maintenance/use of existing auxiliary equipment - pulp and paper mills	energy efficiency	-64.1		0.36		0	3.4.3
3 Improve maintenance and use of existing steam-producing equipment - pulp and paper mills	energy efficiency	-61.3		0.85		0	3.4.3
4 Improve process thermal integration - pulp and paper mills	energy efficiency	-31.8		1.25		0	3.4.1
5 Select energy efficient process technologies - pulp and paper mills	energy efficiency	-24.1		2.68		839	3.4.2
6 Optimize recovery boilers - 35 pulp and paper mills	fuel-switching	-15.2		0.39		65	3.5.3
7 Increase wood waste cogeneration - 12 pulp and paper mills (mills sell excess electricity)	fuel-switching	-11.1		2.46		247	3.5.4
8 Select high energy-efficiency technologies - lumber and panelboard mills	energy efficiency	4.4		0.33		57	3.4.6
9 Plant fast-growing plantations - 50,000 ha planted over 5 years **NOT CONSENSUS**	afforestation	22.2		1.31		141	4.2.3
CATEGORY 2 MEASURES							
10 Select high intensity driers - paper mills	emerging technology	-85.9		0.21		0	3.6.4
11 Black liquor integrated gasification and combined cycle cogeneration - 3 pulp and paper mills (mills sell excess electricity)	emerging technology	-28.5		1.09		0	3.6.2
12 Fuel-switching - lumber and panelboard mills	fuel-switching	-5.4		1.51		356	3.5.5
13 Increase number of hog fuel boilers - 12 pulp and paper mills	fuel-switching	-3.4		1.33		111	3.5.2
14 Modernize of hog fuel boilers - 35 pulp and paper mills	fuel-switching	-2.6		0.48		155	3.5.1
15 Reduce water use through progressive system closure - 10 pulp and paper mills	emerging technology	5.3		0.31		200	3.6.1
16 Develop 2 wood-ethanol plants	other energy	6.8		0.36		119	3.7.1
17 Initiate afforestation program(s) using traditional species		2008-2012	2000-2050	In 2010	Average 2000-2050		
a Prairie block plantations - 260,000 ha planted over 15 years **(NOT CONSENSUS)**	afforestation	115	3	0.37	1.4	214	4.2.5
b Prairie shelterbelts - 169,000 ha planted over 15 years **(NOT CONSENSUS)**	afforestation	141	3.7	0.15	0.6	107	4.2.4
c Eastern block plantations - 195,000 ha planted over 15 years **(NOT CONSENSUS)**	afforestation	145	2.3	0.22	1.4	157	4.2.7
d BC block plantations - 169,000 ha planted over 15 years **(NOT CONSENSUS)**	afforestation	453	2.4	0.04	0.7	86	4.2.6
Total (793,000 ha over 15 yrs) **(NOT CONSENSUS)**		144	2.8	0.78	4.1	564	4.2
18 Policies to increase carbon sequestration on the managed forest **(not currently in Protocol)**	other carbon sequestration	further analysis needed					4.5

Measure and Category of Recommendation	Type of Measure	Cost Effectiveness 1997$ / t CO_2e Reduced or Offset (10% discount)	Direct and Indirect GHG Emission Reduction or Offset, 2010 Mt CO_2e	Estimated Incentive for Realization 1997$ million	Section in Report
19 Modify reforestation methods to increase sequestration **(high negotiating uncertainty) (NOT CONSENSUS)**	reforestation	further analysis needed			4.3.2
20 Implement policies to reduce deforestation **(negotiating uncertainty)**	deforestation	further analysis needed			4.4
CATEGORY 3 MEASURES No measures in this category					
CATEGORY 4 MEASURES					
21 Lignin precipitation / improve recovery boiler operation - 45 pulp and paper mills	emerging technology	20.2	0.22	146	3.6.5
22 Biomass gasification to feed lime kilns - 10 pulp and paper mills	emerging technology	47.1	0.31	287	3.6.3

Note: a negative cost per tonne indicates that the emission reduction is achieved with a net savings.

For each action/measure, Table 5.1.2 shows the estimated cost effectiveness, ghg emission reduction or offset (through increased sequestration) in 2010 and an estimate that we refer to as the 'incentive for realization of the action' (described below). This incentive could be provided in a number of ways which may or may not involve direct funding. The Table also shows the category of recommendation for each measure, based on the categories in the National Secretariat Guidelines for Issue Table Options Report and further described in Section 5.2.

An estimate of negative cost effectiveness means that an action has a net saving, based on the net present value (NPV) of incremental costs and savings. In general, for the energy measures the analysis is based on a comparison of, on the one hand, the choices that we assume would be made in a business-as-usual world during the normal capital replacement cycle in mill, and, on the other hand, potential alternative choices which would reduce ghg emissions. When the time comes to replace equipment a mill will have a choice of various technologies at various capital costs and with varying levels of energy efficiency. The incremental capital cost of choosing the more energy efficient (and usually more expensive) technology is the difference between its cost and the cost of the less energy efficient (and usually cheaper) technology. As the more energy efficient technology is used it will provide energy cost savings over time relative to the less energy efficient technology. Cost effectiveness is the NPV of these incremental costs and savings (derived using a 10% discount rate) divided by the emission reductions or carbon sequestration over the 'life' of the investment. For the energy actions the life is the serviceable life of a new machine.

The concept of the 'life' of the investment is much more difficult to apply to forests, as explained in Section 4.2. Thus for each afforestation measure two cost effectiveness numbers are shown. The first is based on sequestration in 2008-12 while the second is based on total sequestration in 2000-50, which better approximates the 'life' of the afforestation investment. In both cases the incremental cost we use is the NPV (derived using a 10% discount rate) of the planting and land opportunity costs.

We define 'incentive for realization of the action' for the energy actions as the incentive that would have to be provided to make an action financially feasible from the perspective of industry. It is based on the NPV of the action, derived using a pre-tax 40% discount rate. In other words, in order to make an investment financially attractive, we needed to determine the size of the incentive so that the pre-tax NPV of a project, including capital costs and cost savings over time plus the incentive, is equal to zero using a 40% discount rate, i.e., the pre-tax rate of return is 40%. On an after-tax basis, the rate of return would be less than this. The reasons for using a 40% discount rate were explained in Section 3.2. An incentive of zero is shown where the action has net savings in every province/region (i.e., a negative NPV) using a 40% rate. **Note that even though a project is financially feasible (has an acceptable return) from the perspective of industry it may not go ahead because considerations other than financial return also influence investment behaviour (eg. capital availability, risk). Thus, in addition to ensuring an action to reduce emissions is financially feasible, public policy may also need to address these other factors.**

For afforestation, the incentive figures shown are the NPV of the planting and opportunity costs of the afforestation, derived using a 10% discount rate. In fact, federal or provincial government involvement in afforestation might be lower than the numbers suggest - the Table believes that there are many possible groups, such as forestry companies, energy companies, municipalities, conservation authorities and others, who may choose to wholly or partially fund afforestation, as explained in Chapter 4. On the other hand, there will be other costs and benefits which we did not calculate and include in the estimates.

5.1.2 Caveats to Results

In reviewing the results in Table 5.1.2 a number of points made in the Report need to be kept in mind.

1 The measures are not necessarily additive. In particular, the energy measures are not additive, although the carbon sequestration measures are. Section 3.8 provides an estimate of the overall reduction due to overlap and conflicts between energy measures, but it is not possible to net down on an individual basis.

2 The results are very sensitive to our assumptions about energy prices, which were based on the assumptions in *Canada's Energy Outlook*, as explained in Section 3.2. Changes in energy prices as a result of efforts to reduce ghg emissions in Canada or abroad will effect both the cost effectiveness and the incentive required for realization of each energy measure.

3 The estimated incentive required for the realization of each energy measure could be provided in a variety of ways, such as through the tax system, grants or loans. However, generally we do not believe this incentive will always be sufficient to achieve a given action, as impediments to the actions are much more complex than a simple question of attaining a given rate of return. There are other impediments which governments and other stakeholders must address. These include issues of risk, lack of capital, lack of information, and the need for research, development and commercialization of emerging technologies, as discussed in Chapter 3.

4 The afforestation estimates are based on the best available information given the time frame allowed for the analysis but there are still large data gaps and basic information needs that render many of the results uncertain. For example, we could not provide a full accounting of costs and benefits. Costs which we did not include are the costs of forest protection, program operation, and monitoring and verification of carbon sequestration, as well as the cost of potential future carbon debits. The benefits which we did not include are in large part dependent on the eventual use of each afforested area - for example, they could include environmental benefits related to restoration of degraded or fragmented forests, or revenues from harvesting the trees for use in forest products or for bioenergy. There would also be a variety of local employment and economic diversification effects.

5 The afforestation results are based on initiating afforestation in 2001 with a ramp-up to full annual planting targets by 2005. The ability to begin large-scale afforestation programs in 2001 is a very optimistic assumption - start-up in 2002 or 2003 may be more reasonable given the time that will be needed to develop and promote afforestation programs, obtain seedlings and involve landowners. Such a delay will lower the carbon sequestration in the first commitment period.

6 Negotiation outcomes will be a key determinant of the net impacts of reforestation, afforestation, deforestation and additional forest management activities on Canada's target in the first and subsequent commitment periods.

5.2 RECOMMENDATIONS FOR MEASURES

The approach to the national strategy for achieving the Kyoto target is based on developing a core options package for immediate implementation in 2000, as well as considering elements of a longer term package for implementation in the post-2000 period. Implementation means putting in place policies to facilitate the actions. In keeping with this approach, each measure shown in Table 5.1.2 is placed in one of four categories of recommendations depending on the degree of its impact in the first commitment period, its cost effectiveness, the need for further analysis and consultation, and the extent to which future negotiating outcomes will determine its usefulness for meeting Canada's Kyoto target. Many measures require further analysis or consultation, and we suggest they should not be part of the core package to be implemented in 2000. However, this does not mean that policy development for these other measures can be delayed. Rather, development of policies to achieve the actions should also start in 2000.

Details on each of the actions and measures are given in Chapters 3 and 4. In particular, see Table 3.3.1 which summarizes key impediments to the energy and technology actions, and suggests policies which can be used to overcome each barrier. Also see Table 4.2.5 which identifies the key impediments to afforestation and proposes policies which could be part of afforestation programs to overcome them.

The Table was not able to reach consensus on all of its recommendations for measures. Accordingly, Table 5.1.2 indicates where consensus did not exist, and the discussion of each measure in this section describes the varying views about the non-consensus recommendations.

5.2.1 Category 1 Recommendations

This category of recommendations refers to measures that can be implemented immediately (ie. in 2000) and should be part of a package of core measures in Canada's national strategy to reduce its ghg emissions to meet the 2008-12 goal. The effect of the energy measures will occur over time as the forest industry is influenced to invest in energy efficient or fuel-saving technologies.

Recommendation 1:	***Policies to foster forest industry energy efficiency should be implemented immediately***
Key impediment:	*lack of capital*

We estimated that five of the six energy efficiency measures (measures 1 to 5 in Table 5.1.2) have a net savings, while the last (measure 8) is relatively cost effective. Perhaps the most significant impediment to these actions, and the reason why they would not be undertaken in a BAU world, is the lack of access to capital that most forest industry companies face.

Recommendation 2:	***policies to encourage increased development of wood waste cogeneration projects in the pulp and paper industry should be implemented immediately***
Key impediments:	*lack of capital; inability to sell excess electricity at an economic price*

The analysis for this measure (measure 7 in Table 5.1.2) was based on an evaluation of 12 cogeneration projects which are quite advanced in their design but have not proceeded due to economic or regulatory hurdles. These projects could proceed quickly if these hurdles are removed, including barriers created by electricity market pricing and regulation. While future availability of an economic supply of wood residue is a key consideration for such investments, we assume that the proponents of the projects have taken this issue into account in their analysis and design of the projects. Note that the emission reduction, cost effectiveness and incentive shown in Table 5.1.2 for this measure are based on the assumption that mills will be able to sell any excess electricity they produce at a price of $0.04/kWh, which will only be possible with changes to current electricity transmission pricing policies.

Recommendation 3:	***policies to encourage optimization of chemical recovery boilers in pulp and paper mills should be implemented immediately***
Key impediment:	*lack of capital*

This fuel-switching measure (measure 6 in Table 5.1.1) replaces fossil fuel with biomass fuel but does not require increased use of wood residues. Instead, the reduction in fossil fuel is made possible by improving equipment to better use the existing biomass fuel.

Recommendation 4:	***an afforestation program to plant 50,000 ha***
NON-CONSENSUS	***using fast-growing tree species should be implemented immediately***
Key impediments:	*high up-front costs, uncertain participation rates*

Some Table members believe an afforestation program involving planting fast-growing tree species (i.e., measure 9 in Table 5.1.2) should be part of a core set of measures for implementation in 2000. While more expensive to establish than afforestation using other species, the use of fast-growing species would increase the amount of carbon sequestered in the first commitment period. In general, there is still considerable uncertainty about the potential involvement of landowners and others in afforestation, as well as the precise cost and impact of afforestation, especially in the first commitment period. It is likely that the forest products industry will be very interested in participating in this type of afforestation and using the wood either for energy or products such as oriented strand board. A substantial amount of planning would be required to ensure that afforestation was carried out on appropriate sites, and that program incentives were appropriate.

As discussed in Chapter 4, there are a variety of carbon accounting issues which still need to be resolved through negotiations because of the likelihood that fast-growing tree species will be harvested in or soon after the first commitment period. The implications for carbon credits under alternative negotiation outcomes would have to be further investigated, as part of afforestation program development. It should also be noted that only verifiable changes in carbon stocks will provide carbon credits, so a measurement and monitoring system will be a necessary component of any afforestation program.

Some Table members were unable to endorse this recommendation because they feel there are still too many uncertainties to warrant moving forward with afforestation for carbon credits. Many of these unknown factors may significantly reduce the net carbon benefit. They include uncertainties related, for example, to the extent of effective engagement of landowners and lack of clarity on accounting rules, including the treatment of carbon credits and debits following harvest, and the consideration of carbon on-site prior to afforestation. In addition, specific concerns related to fast-growing plantations include significant concerns around environmental impacts and the general appropriateness of fast-growing monoculture plantations or "tree-farms". As well, some Table members felt that there is little point in highlighting fast-growing plantations as a distinct option, because while there is a short term advantage to using fast-growing species, there is no demonstrated long-term advantage to generating afforestation credits with fast-growing species as opposed to traditional native species. Some members questioned the logic of having afforestation of fast-growing species as category 1, and afforestation of traditional species as category 2, when there appear to be more uncertainties related to accounting rules with the former.

Summary of Impact of Category 1 Measures

Combined, the eight consensus forest industry energy measures in this category (measures 1 to 8 in Table 5.1.2) form an options package that could reduce the forest industry's direct and indirect emissions by a maximum of about 9.0 Mt CO_2e in 2010. We believe that the interactions among these actions would reduce the emission reductions by 25-50% but that obtaining sufficient residues for the two fuel-switching actions will not be a problem. Reducing the maximum by 33% to account for the interactions suggests that a sizeable reduction of about 6.0 Mt CO_2e in 2010 is achievable. When subtracted from projected total emissions in 2010 of 23.1 Mt CO_2e this is equivalent to a 15% drop below 1990 direct and indirect emissions (see Table 5.1.1).

We estimate that the incentives required to make these actions financially feasible from the industry perspective would have a maximum value equivalent to 1997$1.2 billion (the actual value could be lower given the interaction among the actions). Other indirect government support or policy change would also be required, as outlined in Section 5.3 below on Recommendations for Policy Directions. In particular, the wood waste cogeneration measure requires changes in electricity transmission pricing.

The non-consensus recommendation for afforestation using fast-growing species, if implemented, would offset ghg emissions by sequestering 1.3 Mt CO_2e in 2010. Planting and land opportunity costs total about 1997$140 million but note that a full accounting of all costs and benefits was not possible. Also note that there are considerable concerns about afforestation on the part of some Table members.

5.2.2 Category 2 Recommendations

These recommendations concern prospective measures that should play a role in Canada's strategy for meeting its emission reduction target but which, for example, require further analytical work and/or broader consultation, or are conditional on international developments, including the outcome of negotiations to refine the Kyoto Protocol. Thus these measures should be the basis for developing a future package of measures to reduce or offset Canada's ghg emissions in 2008-12. While full implementation might not occur in 2000, it should not be delayed much beyond 2000, and policy development should start in 2000.

Recommendation 5:	***policies to enhance forest industry fuel-switching to increase the use of residues above the business-as-usual level should be part of a post-2000 strategy***
Key impediments:	*capital, limited availability of wood residues in many areas*

This recommendation applies to the three fuel-switching measures in this category (measures 12-14 in Table 5.1.2). Fuel-switching in the forest products industry in recent years has reduced its ghg emissions considerably, and this is expected to continue at a modest rate in a BAU world. We believe there is scope for an increased rate of fuel-switching through these actions but the future level of surplus wood residues and their costs represents a key uncertainty, especially east of British Columbia.

Recommendation 6:	***policies to promote emerging technologies and processes related to progressive system closure, black liquor integrated gasification and combined cycle cogeneration and high intensity paper dryers, should be part of a post-2000 strategy***
Key impediments:	*capital, high risk, lack of commercial technology, inability to sell excess electricity at an economic price*

This recommendation covers the three emerging technology measures in this category (measures 10, 11 and 15 in Table 5.1.2). Because these technologies which may only begin to be commercially used over the next ten years or so, their longer term potential to contribute to emission reductions after 2010 could be very substantial. This is especially true of black liquor integrated gasification and combined cycle cogeneration technology. A major need here is for policies which support and encourage research, development, demonstration and commercialization. For the black liquor gasification action, the ability to sell excess electricity is key to obtaining the significant and highly cost effective ghg impact shown in Table 5.1.2. Our estimates for this measure are based on the assumption that mills will be able to sell any excess electricity they produce at a price of $0.04/kWh, which will only be possible with changes to current electricity transmission pricing policies.

Recommendation 7:	***policies to support development of wood ethanol facilities in Canada by 2010 should be part of a post-2000 strategy***
Key impediment:	*lack of commercial technology*

This measure (number 6 in Table 5.1.2) requires investment in accelerated development and commercialization of technologies to produce wood-based ethanol, with the goal of establishing a pilot facility by 2005 and two commercial facilities by 2010. In addition to its potential to reduce ghg emissions in the transportation sector, this measure could create other important environmental benefits, including a reduction in air pollution.

Recommendation 8:	***policies to reduce deforestation should be***
SUBJECT TO	***part of a post-2000 strategy, since emissions from***
NEGOTIATIONS	***deforestation in 2008-2012 must be added to Canada's target***
Key impediments:	*lack of information on the extent and causes of deforestation*

There is a high degree of uncertainty about the extent, causes and location of deforestation. However, it is likely that strategies for reducing deforestation in some areas will be more cost-effective in the short term than afforestation policies. Adjustments to policies must be done cautiously, taking into account economic and other tradeoffs, and much work is needed to better quantify and define the causes of current rates of deforestation.

Recommendation 9:	***policies should be put in place to promote***
SUBJECT TO	***activities in the managed forest which enhance***
NEGOTIATIONS	***carbon sequestration***
Key impediments:	*lack of knowledge on carbon sequestration impacts of specific activities*

In the absence of clarity on how the "managed forest" might fit into the Protocol, Canada's emphasis in its initial National Implementation Strategy should be on measures that have a significant long term net positive impact on forest carbon reservoirs, and that are consistent with sustainable forest management practices and other social and environmental objectives.

If the managed forest is negotiated into the Kyoto Protocol, then increases in carbon stocks in the managed forest will be credited in the first and subsequent commitment periods. If it is not, then increased carbon sequestration will still be of benefit because it reduces CO_2 concentrations in the air, although Canada will not obtain a credit in terms of the Protocol. We believe that policies to achieve increased carbon sequestration on the managed forest could have relatively low cost.

Recommendation 10:	***afforestation programs to plant almost***
NON-CONSENSUS	***800,000 ha in block plantations and shelterbelts using traditional tree species should be part of a post-2000 strategy***
Key impediments:	*high up-front costs, uncertain participation rates*

While some Table members believe the uncertainties about the precise cost and impact of these afforestation measures (numbers 17a to 17d in Table 5.1.2) are simply too significant to warrant undertaking afforestation with the goal of obtaining carbon credits, other Table members believe that these measures will provide substantial and cost effective annual carbon sequestration benefits over the longer term (20-50 years), even if their impact in the first commitment period is small and very uncertain. Therefore, they argue that, while the major impact is of a longer term nature, the earlier that programs are developed and implemented the earlier will be the impact. Some members thought that this recommendation should be in category 1. See also the discussion under recommendation 4. It should be noted that under some international negotiation outcomes, shelterbelts may not be included under a definition of afforestation (or reforestation).

Recommendation 11:	***policies to encourage modification of***
NON-CONSENSUS	***reforestation methods to increase carbon***
SUBJECT TO	***sequestration on areas reforested since 1990***
NEGOTIATIONS	***should be considered for inclusion in a post 2000 strategy***

The negotiation of definitions for RAD is key to the relevance of strategies to modify management methods to enhance carbon sequestration on areas reforested since 1990, but this will not be decided until late 2000 at the very earliest. Given the range of possible negotiating results, and uncertainties in the effect of modified reforestation methods on carbon sequestration, estimates of the impact could not be provided. Some Table members thought that work should continue on understanding these effects (in terms of costs, ghg impacts, and policy requirements) in order to allow implementation of modified methods (depending upon negotiation outcomes). Methods to enhance carbon sequestration on areas regenerating after harvest would also be applicable under a managed forest approach. Other Table members could not support this recommendation because of concerns that a definition of reforestation which includes regeneration after harvest (which is implicit in Canada's suggested working definition) has implications that undermine the Framework Convention on Climate Change and risks providing perverse incentives that are contrary to good forest management.

Summary of Impact of Category 2 Measures

Collectively, the consensus recommendations regarding the six forest industry energy and technology measures included in this category (measures 10-15 in Table 5.1.2) would have a maximum emission reduction impact of 4.9 Mt CO_2e in 2010. However, we think their combined impact is likely to be much lower due to interactions among the measures and the effect of residues shortages in many parts of the country. Thus we expect that these six measures could reduce emissions by roughly 2.0 Mt CO_2e in 2010, after accounting for these effects.

We estimate that the incentives required to make these actions financially feasible from the industry perspective would have a maximum value equivalent to about 1997$0.9 billion (the actual value could be lower given the interaction among the actions). In addition, government support would be required to address the other impediments including lack of capital, high risk, and the inability to sell excess electricity at economic prices.

The wood ethanol measure (measure 16 in Table 5.1.2) will reduce emissions by 0.36 Mt CO_2e by replacing gasoline with a blend of gasoline and biomass-based fuel. We estimated that the incentive required for realization would have a value of $120 million, but development, demonstration and commercialization of the technology would require additional support.

The Table did not reach a consensus on the advisability of the measures involving afforestation of almost 800,000 ha over 15 years. If implemented, these afforestation measures collectively would provide an emission offset of 0.8 Mt CO_2 in 2010, though the longer term annual emission offset would be much higher - the average annual offset to 2050 is 4.1 Mt CO_2e per year, or a total of over 200 Mt over the 50 years. The upfront planting and opportunity cost of planting 800,000 ha over 15 years is about 1997$0.6 billion, but there would be other costs and benefits as well which we were not able to estimate. A delay in the start-up date from 2001 to 2002 or 2003, which may be more realistic, will reduce the emission offset by roughly 35%. One reason for the lack of consensus on these measures is that some Table members question the reliability of the above figures, given the uncertainties that have not been accounted for.

5.2.3. Category 3 Recommendations

This category of recommendations refers to measures which merit further consideration but are longer term require additional analysis/information for inclusion in the evolution of the strategy post-2000. The Table did not assign any of the measures it assessed to this category. Although the afforestation measures are long-term, and would therefore appear to belong in this category, Table members felt that they were best dealt with in Category 2 because action must be taken soon in order to obtain significant benefit even several decades into the future.

5.2.4 Category 4 Recommendations

This category includes all measures that the Table concluded do not merit further consideration, as demonstrated by the results of its assessment.

Recommendation 12: ***biomass gasification for lime kilns and lignin precipitation should not be part of Canada's strategy***

We base this recommendation on the low cost effectiveness of these measures and their relatively small impact on emissions compared to other measures analyzed. However, we emphasize that, while these two actions (numbers 21 and 22 in Table 5.1.2) were judged to be less suitable for reducing emissions than other actions, there could be other reasons for undertaking the actions from the perspective of mills. Our recommendation is based only on their relative merit for contributing to Canada's ghg emission reduction target. As well, these actions were considered only in the context of the analysis done by the Forest Sector Table. In a broader context, they could well prove to be relatively cost effective means of reducing emissions.

5.3 RECOMMENDATIONS FOR POLICY DIRECTIONS

The development of a National Implementation Strategy for the Kyoto Protocol creates a range of serious risks and uncertainties for Canada's forest sector. However, the Forest Sector Table believes that it is possible to develop a strategy which will allow the forest sector to build on its past success and continue to make a substantial contribution toward ghg mitigation without unduly disadvantaging any stakeholder group. The quality of Canada's public policy response to Kyoto implementation will be the key determinant of the extent to which ghg reductions can be achieved in a fair and cost-effective manner. In this report, we have put forward a number of policy principles and proposals for consideration in the development of a National Implementation Strategy. In many cases, additional research and consultation is required before these policies and options could be implemented. However, we believe that our work can form the basis of a strategy for the forest sector to make a substantial contribution to ghg mitigation, including the identification of principles and directions for the development of policies in support of such a strategy.

5.3.1 Principles and Directions for a National Implementation Strategy

The Forest Sector Table believes the following principles should be part of the development of the Strategy:

1 That the continued involvement of representatives of all stakeholder groups in the development of a National Implementation Strategy is critical, given the far-reaching implications of Kyoto for all segments of Canadian society. Care must be taken to maintain appropriate balance between stakeholder groups.

2 That a National Implementation Strategy recognize the uncertainties associated with the Protocol itself and the response of Canada's trading partners to it by being flexible so that Canada's strategy can adapt to international developments as they evolve.

3 That implementation is most likely to achieve mitigation targets in a timely and cost-effective manner if it relies on broadly based market-oriented policy instruments and approaches, accompanied by effective regulatory frameworks and the removal of inappropriate incentives and disincentives.

4 That the timely removal of uncertainties around systems of credit for early action and baseline protection are key to their potential contribution to a National Implementation Strategy.

5 That the competitive, employment, health and environmental impacts of both a National Implementation Strategy as a whole, and the individual measures proposed as part of it, need to be more fully determined.

6 That use be made of full life-cycle and systems approaches in policy development wherever possible, including in the development of building codes and standards.

5.3.2 Core Policy Requirements - Energy and Technology Measures

In this Report, the Forest Sector Table has articulated its belief that the energy actions it has evaluated could cumulatively make a significant contribution toward reducing direct and indirect ghg emissions of the forest products industry. However, it should be emphasized that these opportunities tend to be very localized in nature. For example, all of the fuel switching actions presented in this report are dependent on a locally available supply of wood residues or other suitable biomass feedstock as a fuel supply. Similarly, the relationship between energy efficiency and ghg intensity is complicated in the forest industry by the fact that each mill uses a different mix of fuels with varying carbon intensities to meet its energy needs. For these reasons, the feasibility and cost-effectiveness of actions to reduce ghg emissions in this industry vary widely across regions, industry-sectors and from one mill to the next. As a result, conventional regulatory approaches seem unlikely in most cases to provide a cost-effective means of reducing ghg emissions in the forest industry.

In Chapter 3 of this report, the Table identified significant impediments to action, as well as a wide range of changes in government policies and other means to encourage ghg reductions within the sector. Each of these types of policies should be fully considered in the development of Canada's National Implementation Strategy. However, we believe that the three policy areas identified below are of critical importance in allowing the forest industry to realize its considerable potential to contribute to Canada's Kyoto response. These three policy areas deserve particular attention.

With timely action by governments in these key areas and provided that other measures taken as part of the National Implementation Strategy do not, on a net basis, undermine the ability of the sector to undertake new investments, we believe that the forest industry can rapidly initiate actions which would allow it to make a disproportionate contribution toward the achievement of Canada's Kyoto effort.

Provide fiscal incentives to reduce capital constraints: The Forest Sector Table believes that the industry's financial position and resulting difficulties in raising capital represent a major, likely the major, impediment to the realization of investments that could substantially reduce its ghg emissions. The Table believes that fiscal incentives provide a rapid, efficient and cost-effective means of creating the needed inducement to attract investment in these actions. In Table 5.1.2, an estimate of the magnitude of the incentive required to realize each action was provided. However, the Table believes that broadly based fiscal incentives for fuel switching and energy efficiency enhancements provide the most efficient and neutral means of reducing emissions from their "business-as-usual" levels. In theory, incentives could be delivered through a funded government program rather than a tax expenditure; however, the Table believes the latter approach is likely to entail lower administrative costs both for governments and industry, although it is preferable that new measures simplify and not further complicate the tax system.

Provide policies to encourage renewable energy: The Forest Sector Table believes that the use of forest biomass as an energy source in many settings holds tremendous potential to contribute to Canada's Kyoto response. Within the forest sector, many of Canada's competitor nations have enjoyed considerable success in exploiting this opportunity through the development of a policy environment which actively encourages the sector to maximize its use of this energy source. The Forest Sector Table believes that a more supportive policy environment could allow many segments of the Canadian forest industry to also become net sources of renewable energy. Central to realizing this opportunity is the establishment of electricity markets where mills can sell any excess power they generate either into the grid or directly to users at fair prices. For example, the establishment of renewable energy set-asides, similar to those in place in many US states and as proposed federally in the US, could play a key role in increasing the use of biomass cogeneration within the Canadian forest industry.

Encourage technology and innovation: As one of Canada's leading consumers of high technology machinery and equipment, the development and commercialization of new technologies holds considerable potential to contribute to reducing the forest industry's ghg emissions. This paper describes the potential of several emerging technologies that could play a role in Canada's Kyoto solution, some of which are the subject of intensive, multi-stakeholder research efforts in competing countries. The Table believes that a concerted research and development effort involving all stakeholders in Canada's forest industry research community is a priority element for engaging this sector in a Kyoto strategy. A key focus of such an effort should be encouraging the commercial application of promising new technologies. The risks to an individual company of being one of the first to adopt a new technology are considerable while the benefits tend to be shared across the industry as a whole. While this issue is not unique to the forest sector, the industry's financial position and the high capital costs associated with many new technologies tend to exacerbate this problem within the forest sector. Innovative programs which serve to reduce or share the risks associated with this critical step in the innovation process could help to accelerate technology development and penetration rates. Not only could such programs serve to maximize the potential of technology to contribute to a Kyoto response, but they could also help to create knowledge-based jobs and export opportunities for Canadians.

5.4 ADDITIONAL RECOMMENDATIONS

The Table had a limited time in which to undertake its analysis. As a result, we were not able to assess all actions that we would have like to, and we also were unable to fully address a number of important background issues which would have improved our estimates. This section makes recommendations for further work in these two areas. All the recommendations have consensus support.

5.4.1 Recommendations for Further Actions and Measures Analysis

The Table did not analyze every action identified in its Actions Matrix. During the course of its analysis and discussion the Table identified a number of these actions that it feels especially merit investigation. Some Table members were particularly concerned that a variety of potentially important actions were not assessed. We believe that each of the non-analyzed actions should be subject to at least some initial investigation.

Recommendation: ***assess the effect of increased use of recycled fibres on pulp and paper industry emissions***

In general, the pulping and production of paper or paperboard using recycled fibres requires less energy than does production using virgin fibre. However, collecting and transporting heavy loads of recycled fibre from major urban centres to paper mills can be quite costly, and could result in greater transportation emissions than the transport of an equivalent quantity of virgin fibre, given the current location of many pulp and paper mills. The net effect of these factors needs to be considered for Canada.

Recommendation: ***explore the potential of improving energy efficiency in logging and silviculture operations***

There may be cost-effective ways to reduce emissions in logging and silviculture operations. Relatively little is known about energy use and ghg emissions of these operations, and any effort to assess how they could reduce their energy use will first have to develop a better understanding of these emissions.

Recommendation: ***assess the ghg emission impacts of transportation services used by the forest industry, and ways to reduce the emissions***

The Transportation Table is examining some of the transportation services used by the forest industry but a complete assessment of the energy use and ghg emission impacts of the upstream (logging, silviculture, transport of logs to mills) and downstream (transport of products to buyers) transportation services used has not been done.

Recommendation: ***assess the potential for fuel-switching to wood biomass outside the forest industry***

There may be important opportunities to increase the use of wood biomass as a fuel for district heating and residential wood burning, especially in remote communities, or for power plants. One important issue is the likely availability of wood biomass for non-industrial energy uses, and the possible role of afforestation and other sources in meeting any shortfall.

Recommendation: ***continue to improve our understanding of the causes, location and extent of deforestation, and ways to reduce its impact***

Analysis for the Table provided what is, to date, the best assessment of deforestation in Canada, although major information gaps remain. Policies to address deforestation from all sources need to be considered, because of the potentially large negative impact of deforestation on CO_2 emissions.

Recommendation: ***there is a very high priority to determine the implications for Canada of including the managed forest and storage of carbon in forest products in the Protocol***

Activities on the full managed forest area may be negotiated into the Protocol, and further work is needed to determine the impacts of actions to increase CO_2 sequestration both onsite in the managed forests and offsite as a result of carbon storage in wood products. The costs of these actions, and the policy changes that would be required to implement these actions, are also important to determine. The potential benefits are thought by some to be much greater than those from reforestation, afforestation and deforestation activities since 1990, which currently are the only forest-related activities included in the Protocol. There is also a very high priority to determine the implications for Canada under various negotiation outcomes related to including the managed forest in the Protocol. Canada should negotiate for the inclusion in the Protocol of carbon credits for storage of carbon in forest products, but in a way that does not prejudice Canada for being a large exporter of products.

Recommendation: ***investigate the carbon sequestration and energy-saving impacts of urban forestry***

Urban forestry involves the planting of trees in urban setting, whether by individuals on their own property or through municipal efforts in parks and along streets. Such planting sequesters carbon and can result in reduced fossil fuel emissions through reductions in energy requirements for air-conditioning and heating. There is uncertainty as to whether this sort of tree planting would qualify as afforestation under the Protocol, an uncertainty that will not be resolved until late 2000 at the earliest. However, urban planting could play an important role in helping to engage Canadians in issues related to climate change, the Kyoto Protocol and the National Implementation Strategy.

5.4.2 Recommendations for Further Background Work

Recommendation: ***improve information on availability of biomass wastes for energy***

Despite the background work undertaken for the Forest Sector Table, there still remains considerable uncertainty about the current level, distribution and quality of surplus wood residues in some parts of the country, and especially about these characteristics in the future. As well, the level, distribution and usefulness of other sources of wood waste or agricultural and municipal wastes which could be used for energy are uncertain.

Recommendation: ***improve information on tree growth and yield, and changes in all carbon pools over time***

The analysis of afforestation, reforestation and activities on the managed forest all suffered from important gaps in information on tree growth and changes in forest carbon pools over time and in response to human activities. In particular, we need to improve information on tree growth and yield, and root, soil and litter carbon changes over time for young stands of trees (eg. the first 20-30 years of growth), intensively managed plantations, and second-growth forests, including differences in managed and unmanaged stands. This sort of information is needed for a broad variety of species and species mixes as different species and mixes are appropriate for different parts of the country, and for different purposes.

Recommendation: ***improve information on factors which determine the cost and impact of afforestation programs***

As discussed in Section 4.2, the total cost and long term carbon sequestration impact of afforestation programs will depend on a large number of factors other than tree growth rates and carbon pool changes, many of which have significant uncertainty associated with them. These uncertainties include factors related to the implementation, operation and success of afforestation programs, such as the likely uptake rate of potential participants in afforestation programs and the extent of various important costs (land opportunity costs, protection costs, administration costs such as those related to publicity, extension services). In terms of the long-term carbon impact, there needs to be consideration of the impact of potential program drop-off (land owners who afforest for a period and then remove the forest) and the associated deforestation liability, and the impact on carbon credits and debits of harvesting, fire and pests. More generally, the ultimate end-use of afforested areas will have an impact on the flows of carbon credits and potential debits over time that will be counted. An assessment is also needed of emissions resulting from site treatment, including planting, biocide application, fertilizer use and harvesting. Finally, there needs to be consideration of a wider range of species including shrub species.

Recommendation: ***investigate potential ownership rules for carbon credits and debit on public lands under tenure arrangements with private companies***

While the analysis in this report focussed on afforestation on privately owned land, some afforestation could take place on public land. Deforestation could also occur on publically owned land. As well, while negotiating outcomes are uncertain, it is possible that at some point carbon credits (debits) will result from activities which increase (decrease) carbon sequestration through modified reforestation or other practices on public land. Legal and financial issues related to the ownership of the carbon credits and debits need to be analyzed.

Recommendation: ***determine carbon sequestration impact and costs of forest management activities on forest carbon pools over time***

While some analysis of the impact of specific forest management activities on carbon pools have been done it is clear that more analysis is needed to refine these estimates and determine the extent to which impacts and costs can be generalized or are site or region specific. More, generally, we need to develop a better understanding of the net effect of including the managed forest in the Kyoto Protocol, and determine what are the most cost effective ways to increase the carbon sequestration of the managed forest while at the same time ensuring sustainable forest management and consideration of other environmental goals. We also need to develop a better understanding of the impact of natural disturbances (naturally occurring fire, pests) on the managed forest.

Recommendation: ***improve information on the impact and cost of actions to modify carbon storage of carbon in forest product carbon pools, and their links to onsite carbon storage in all pools over time***

At present, changes in the forest products carbon pool are not included in the Kyoto Protocol and there is also no international agreement on how these changes should be accounted for in national greenhouse gas inventories. We need to better understand how these pools change over time (eg. the rate of decay of products based on the type of product and type of use), how best to account for the changes, and how to increase the size of the forest products carbon pool such as through strategies to increase the longevity and durability of forest products. When looking at how to increase the size of the pool we also need to consider the related energy impacts that might result from shifts or changes in logging, manufacturing and transportation operations.

Recommendation: ***continue the development of systems to measure changes in carbon stock resulting from afforestation, deforestation and reforestation and other activities on the managed forest***

The Kyoto Protocol specifies that the carbon impact of reforestation, afforestation, deforestation (however defined) and any other forestry activity added to the Protocol must be measured as the verifiable change in carbon stocks in the commitment period. At present Canada does not have measurement systems capable of meeting this requirement. If Canada is to comply with the Protocol and obtain credits for those activities which increase carbon sequestration, we will need to develop a system to measure verifiable changes in stocks.

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Note: See also Annex A for Analytical Studies Commissioned by the Forest Sector Table.

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ANNEX A - ANALYTICAL STUDIES COMMISSIONED BY THE FOREST SECTOR TABLE

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